Aalto University
School of Engineering

# The environmental impact of service oriented companies

Master's Thesis
Department of Built Environment
School of Engineering
Aalto University

Esbo, 23 November 2017

Bachelor of Science in Technology Jennifer Pitkänen

Supervisor: Professor Seppo Junnila
Advisor: M.Sc Timo Rintala

**Aalto University**
**School of Engineering**

**Aalto University, P.O. BOX 11000, 00076 AALTO**
**www.aalto.fi**

**Abstract of master's thesis**

**Author** Jennifer Pitkänen B.Sc.

**Title of thesis** The environmental impact of service oriented companies

**Degree programme** Master's Degree Programme in Creative Sustainability

**Major** Creative Sustainability in Real Estate **Code** IA3026

**Thesis supervisor** Professor Seppo Junnila

**Thesis advisor(s)** M.Sc. Timo Rintala

**Date** 23.11.2017 **Number of pages** 97 **Language** English

The service sector is not traditionally seen as an emission intensive sector with a great environmental impact. The service sector is, however, economically a large and fast-growing sector and consequently the absolute emissions will grow. Even though a shift to a more service-oriented economy decreases the greenhouse gas (GHG) emissions intensity per unit GDP it does not in itself imply that the GHG emissions would decrease in absolute terms.

To improve the environmental performance of service oriented companies, the negative environmental impacts must be identified and measured. A framework mentioned in several guidelines for studying the environmental impact, is the life cycle assessment (LCA) framework. Based on the LCA framework, a methodology called carbon footprinting has been developed to assess the environmental impact. The carbon footprint methodology is broadly used by companies and organisations to examine and understand the GHG emissions occurring from products, services and processes.

The overall objective of the study is to get an overview of the environmental impact of service oriented companies, focusing on climate change. The aim is to find the relevant components for calculating the carbon footprint of a service oriented company and determine which activities and variables that stand for most of the emissions. The methodology used in this study is the life cycle assessment (LCA). Two applications of the methodology; input-output LCA (IO-LCA) and hybrid LCA, have been applied. The assessment follows the GHG protocol for boundary definition and guidelines. A case study was performed on one digital service creation company located in Helsinki, Finland. The included environmental impacts are limited to climate change and $CO_2$ equivalents, which is the definition and unit of carbon footprint in this study. The study compares three different LCA models and analyses the difference between national and international models. Additionally, the relationship between costs and emissions are analysed.

Previous research suggests that the service sector should focus on office premises and business travel as these in general are perceived to cause most of the emissions. This study, however, shows that such generalisation cannot be made for service oriented companies as they represent a large variety of businesses. The three different models gave surprisingly similar results, mostly due to modest sized office premises and lack of detailed process information for the hybrid LCA. In the case study company business travel stands for most of the emissions (29 %). Commuting does not cause significant emissions and the remaining categories have similar magnitudes of emissions. The total emissions are approximately 1 400 $tCO_2eq$. Compared to previous studies the studied company's emissions are lower than average. No direct correlation between costs and emissions was found.

**Keywords** Carbon footprint, corporate responsibility, environmental impact, hybrid LCA, life cycle assessment, service oriented company, sustainable development

**Aalto-universitetet**
**Högskolan för ingenjörsvetenskaper**

**Aalto-universitetet, PB 11000, 00076 AALTO**
**www.aalto.fi**

**Sammandrag av diplomarbetet**

**Författare** Jennifer Pitkänen B.Sc.

**Titel** Miljöpåverkan av serviceorienterade företag

**Utbildningsprogram** Master's Degree Programme in Creative Sustainability

**Huvud-/biämne** Creative Sustainability in Real Estate **Kod** IA3026

**Övervakare** Professor Seppo Junnila

**Handledare** DI Timo Rintala

**Datum** 23.11.2017 **Sidantal** 97 **Språk** Engelska

Traditionellt sett är servicesektorn inte sedd som en utsläppsintensiv sektor med stor miljöpåverkan. Servicesektorn är dock en stor och snabbväxandesektor ekonomiskt sett och följaktligen kommer de absoluta utsläppen att öka. Även om en övergång till en mera serviceorienterad ekonomi minskar intensiteten av utsläppen av växthusgaser per enhet BNP, betyder det inte i sig att växthusgasutsläppen skulle minska i absoluta mått.

För att förbättra miljöprestandan av serviceinriktade företag, måste de negativa miljöpåverkningarna identifieras och mätas. Ett ramverk för att studera miljöpåverkan, som nämns i flera riktlinjer, är livscykelanalys (LCA). Baserat på LCA ramverket har en metod för att räkna ut koldioxidavtrycket utvecklats för att utvärdera miljöpåverkan. Metoden används i stor utsträckning av företag och organisationer för att undersöka och förstå växthusgasutsläppen från produkter, tjänster och processer.

Det övergripande målet med den här studien är att få en överblick över serviceorienterade företags miljöpåverkan, med fokus på klimatförändringen. Syftet är att hitta de relevanta komponenterna för att räkna ut koldioxidavtrycket av ett serviceorienterat företag och att avgöra vilka aktiviteter och variabler som står för mest utsläpp. Metoden som används i denna studie är LCA. Två tillämpningar av LCA har använts; indata-utdata LCA (IO-LCA) och hybrid LCA. Bedömningen följer växthusgas protokollet (the GHG protocol) för fastställande av uträkningens gränser och som riktlinje. En fallstudie utfördes på ett företag som i huvudsak designar mjukvara och är beläget i Helsingfors, Finland. De inkluderade miljöpåverkningarna är begränsade till klimatförändringen och $CO_2$ ekvivalenter, vilket är definitionen och enheten för koldioxidavtryck i denna studie. Studien jämför tre olika LCA modeller och analyserar avvikelserna mellan nationella och internationella modeller. Därtill analyseras förhållandet mellan kostnader och utsläpp.

Tidigare forskning föreslår att serviceorienterade företag borde fokusera på affärslokaler och affärsresor, eftersom dessa oftast står för största delen av ett företags utsläpp. Den här studien visar emellertid att en sådan generalisering inte går att göra för serviceorienterade företag som representerar en bred variation av affärsverksamhet. De tre olika modellerna gav överraskande lika resultat, mest beroende på den ringa storleken på affärslokalerna och brist på detaljerad process information för hybrid LCA modellen. I fallstudien står affärsresande för största delen av företagets utsläpp (29 %). Pendling till och från arbetsplatsen orsakar inte betydande utsläpp och de resterande kategorierna står för liknande omfattningar av utsläpp. De totala växthusgasutsläppen är ca 1 400 $tCO_2eq$. Jämfört med tidigare studier är utsläppen för fallstudiens företag i den lägre ändan. Inga direkta korrelationer mellan kostnader och utsläpp kunde hittas.

**Nyckelord** Företagsansvar, hybrid LCA, hållbar utveckling, koldioxidavtryck, livscykelanalys, LCA, miljöpåverkan, serviceorienterat företag

## Foreword

This master's thesis defines the end of my time as a student. For most of my life I have been studying and learning, first in school and then at the University. It has been a great journey filled with both joy, happiness and laughter as well as frustration, dejection and sleepless nights. It has given me many friends for life, a broad network, invaluable experiences and of course a lot of knowledge as a base for my future career. Now it is thus time to take a step out to the real world and continue learning there.

This work started as an e-mail where the case company Futurice looked for someone to calculate their carbon footprint. Together then with my current employer Green Building Partners Ltd. I was able to frame a research topic which was in the interest for all three parts; me, Futurice and my employer. I am very grateful for the opportunity that was given to me and I want to thank especially my instructor Timo Rintala at Green Building Partners for all the support and knowledge he brought into the work. I also want to thank Sebi Tauciuc at Futurice for his valuable inputs and comments as well as all the help with the gathering of data. I would also like to thank my supervisor professor Seppo Junnila who has helped me throughout the process with advice, material and insights as well as all other parts who have helped to provide me with information and data for my work.

Everyone at Green Building Partners deserves thanks for giving me the space and time I have needed in order to finish my studies as well as for the support and encouragement. Also throughout my studies the flexibility and understanding that they have given me has been of great importance and a contributing factor to the fact that I am where I am today.

My fiancé Andy deserves special thanks for standing by me all the way. Without his support I would not have come this far. I also want to thank my family who has encouraged all my choices and always been there for me. A special thank to my dad who several times has taken the time to help me when I have needed it. I am very thankful for all my fellow students who have helped me with courses, my friends whose mental support has been indescribably valuable and my CS-family for the support during thesis writing. Without any of you this would not have been as fun, easy and doable.

Esbo, 23nd of November, 2017

Jennifer Pitkänen

## Table of content

Table of content ........................................................................................................

1. Introduction ........................................................................................................ 1

  1.1 Background ........................................................................................................ 1

  1.2 Objective and scope of the study ........................................................................ 2

  1.3 Methodology ........................................................................................................ 3

  1.4 Structure of the work ........................................................................................ 3

2 Sustainable development ........................................................................................ 5

  2.1 Climate Change ........................................................................................................ 5

  2.2 UN climate goals ........................................................................................................ 8

  2.3 EU Climate Action ........................................................................................................ 8

    2.3.1 EU 2020 strategy ........................................................................................ 9

    2.3.2 Future of the EU Climate Action ........................................................................ 11

  2.4 Sustainability within companies ........................................................................ 12

    2.4.1 Corporate responsibility ........................................................................ 12

    2.4.2 Corporate sustainability ........................................................................ 13

    2.4.1 Responsible corporate adaption ........................................................................ 13

  2.5 Enhancing environmental responsible behaviour ........................................................ 14

3 Environmental impact of service oriented companies ........................................................ 17

  3.1 The environmental impact of IT ........................................................................ 17

    3.1.1 Green IT ........................................................................................................ 18

  3.2 Comparison of studies on the carbon footprint of service oriented companies ......... 21

    3.2.1 Presenting the cases and LCAs ........................................................................ 22

    3.2.2 Comparison by impact category ........................................................................ 23

    3.2.3 Empirical comparison of different LCA methods ........................................................ 28

    3.2.4 Environmental impact of energy ........................................................................ 29

    3.2.5 Environmental impact of transportation ........................................................ 31

    3.2.6 Importance of waste management ........................................................................ 32

    3.2.7 Scenario analysis and impact intensity ........................................................ 33

    3.2.8 Examples of possible improvements ........................................................................ 34

    3.2.9 Conclusion of comparison ........................................................................ 34

4 Determining the environmental impact ........ 35
4.1 Life cycle assessment ........ 35
4.2 Carbon footprint ........ 37
4.3 Calculation methods ........ 39
4.3.1 Process LCA ........ 39
4.3.2 Input-Output LCA ........ 40
4.3.3 Hybrid-LCA ........ 41
4.4 Standards and guidelines for GHG accounting ........ 42
4.4.1 The GHG Protocol ........ 42
4.4.2 Other standards and guidelines ........ 44
5 Conclusions of literature review ........ 47
6 Research design and methods ........ 49
6.1 System boundary and data ........ 49
6.1.1 Impact assessment ........ 50
6.2 Assessment models ........ 50
6.2.1 IO-model ENVIMAT ........ 50
6.2.2 EIO-LCA by Carnegie Mellon University ........ 51
6.2.3 Hybrid LCA ........ 51
7 Case study ........ 52
7.1 Company presentation ........ 52
7.2 Personnel questionnaire ........ 52
7.2.1 Commuting ........ 53
7.2.2 Tele- and videoconferencing ........ 55
7.2.3 Office equipment energy ........ 57
7.2.4 Recycling ........ 58
7.2.5 Summary personnel questionnaire ........ 61
7.3 Carbon footprint research process and data ........ 61
7.3.1 Energy and water ........ 62
7.3.2 Waste ........ 62
7.3.3 Commuting ........ 63
7.3.4 Inventory analysis ........ 63
7.4 Results ........ 65
7.4.1 Total emissions ........ 65

7.4.2 Carbon intensity per employee ........ 66
7.4.3 Carbon efficiency and intensity ........ 67
7.4.4 Comparison to earlier research ........ 68
7.4.5 Comparison to conducted input-output LCAs ........ 69
7.5 Possible improvements ........ 71
7.6 Data quality and sensitivity analysis ........ 72
7.6.1 Data quality assessment ........ 72
7.6.2 Sensitivity analysis ........ 73
8 Discussion ........ 76
8.1 Evaluation of results ........ 77
8.1.1 Business travel and commuting ........ 77
8.1.2 Office premises ........ 77
8.1.3 Office equipment and supplies ........ 78
8.1.4 Activities within the company ........ 79
8.1.5 Purchased services ........ 79
8.2 Relationship between emissions and money ........ 80
8.3 Possible improvements in the case company ........ 81
8.3.1 Improvements requiring financial measures ........ 82
8.3.2 Improvements requiring behavioural changes ........ 83
8.4 Limitation of the study ........ 84
8.5 Recommendations for further research ........ 85
9 Conclusion ........ 87
References ........ 89
Appendix A Online Personnel Survey ........
Appendix B Matching of accounting records and IO-data ........

# List of figures and tables


Figure 1 Global anthropogenic $CO_2$ emissions from burning fossil fuel, cement production, flaring, forestry and other land use. The bar on the right shows these sources' cumulative $CO_2$ emissions as well as their uncertainties. (IPCC 2014, p. 3.) .......... 5
Figure 2 For a 50 % chance for the global mean temperature to stay below a 1,5 °C respective 2 °C increase in temperature the $CO_2$-equivavlent levels should not exceed concentrations of 430 respective 530 ppm (EEA 2016). .......... 6
Figure 3 Status of the PBs in 2015. The green zone is the safe operating space, yellow is the zone of uncertainty and the red is the risk-zone. The PB itself is at the inner bold circle. Three of the boundaries are already in the high risk zone and two more in the uncertainty zone. (Steffen et al. 2015) .......... 7
Figure 4 Factors that influence environmentally responsible behaviour (Koivisto 2008, pp. 71, 140) .......... 15
Figure 5 Comparison of LCAs made for service oriented companies, expressed in percentages of total emissions. From left to right: (1) Shrake et al. (2013) hybrid-LCA of a company situated in the U.S., (2-6) Junnila (2004) hybrid-LCA of five companies situated in Finland, (7) Junnila (2006a) hybrid-LCA, creating a base case based on six companies situated in Finland and one in the U.S., (8) Junnila (2006b) PRO-LCA of a company situated in Finland, (9) Junnila (2006b) IO-LCA for same company as case 8, (10-13) Junnila (2006c) hybrid-LCA of the companies based in Finland and one in the U.S, (14-17) Junnila (2009) process based hybrid-LCA of the same companies as in cases 10-13. The scope of all the LCAs covers one-year operation of the service sector companies studied .......... 22
Figure 6 Emissions caused by the office premises for cases 1-17. The median of all the cases is also presented in the figure. .......... 24
Figure 7 Emissions caused by business travel (purple) and commuting (orange) for cases 1-17. The median of all the cases is also presented in the figure. .......... 25
Figure 8 Emissions caused by office supplies for cases 1-4 and 8-17. In cases 5-7 the impact from office supplies was 0. The median of all the cases is also presented in the figure. .......... 26
Figure 9 Emissions caused by office equipment for cases 1-17. The median of all the cases is also presented in the figure. .......... 26
Figure 10 Emissions caused by purchased services for cases 1 and 8-17. In the remaining cases, the impact from purchased services was left out. The median of the cases is also presented in the figure. .......... 27
Figure 11 Empirical comparison of PRO-LCA and IO-LCA (PE = premises, electricity; PH =premises, heat; PC = premises, construction; TF = travel, flights; TC = travel, cars; TB = travel, buses and other public transportation; EE = office equipment electricity; EF = office furniture; EM = office equipment manufacturing; SC = supplies, copy paper; SB = supplies, books and papers; SP=) supplies, pens etc.; PS = purchased services). (Junnila, 2006b, pp. 7072-7073.) .......... 28
Figure 12 Comparison of a hybrid-LCA (dark blue) and IO-LCA (light blue) for a service oriented company (Shrake et al. 2013, p.269). .......... 29
Figure 13 Electricity generation by energy source for Finland (outer circle) and U.S. (inner circle) (EIA 2017; OSF 2016). .......... 30
Figure 14 Life-cycle GHG emissions from selected energy technologies (Weisser, 2007) .......... 30
Figure 15 GHG intensity of different passenger modes in 2005. The clear line shows the world average and the bars Mobility Model (MoMo) region's divergence. (OECD/IEA, 2009, p. 52.) .......... 31
Figure 16 $CO_2$ emissions from passenger transport (EEA 2014) .......... 32
Figure 17 The environmental contribution (proportion of the aggregated normalised impacts) and the impact intensity (aggregated normalised impacts per costs) of the main processes in four service oriented companies. (Junnila, 2009, p. 431) .......... 33
Figure 18 The SETAC-triangle (Koroneos C.J. and Koroneos Y. 2007, p.427) .......... 35
Figure 19 The ISO-LCA methodology (Klöpffer 1997, p. 225) .......... 36
Figure 20 An overview of the three GHG protocol scopes and the emissions across the value chain (GHG Protocol 2011, p. 5) .......... 43
Figure 21 Commuting habits during an average week. Figure 21a describes the percental division between the used transportation options during a week in the winter / autumn and figure 21b during summer / spring.

To clarify it means that e.g. during an average week in the winter 79 % of the commuting trips are done by public transport. ........ 53
Figure 22 People's willingness (possibility) to change commuting habits ........ 54
Figure 23 Results of how often people estimate that they use tele- and videoconferencing in average ........ 55
Figure 24 The figure shows the satisfaction of the current opportunities offered for tele- and videoconferencing ........ 56
Figure 25 The employees do not find in very easy to increase their use of teleconferencing in their work ........ 57
Figure 26 The figure shows the average time it takes for the computers of the employees to go to sleep mode. The majority turns them off when not using them actively which is a good habit and reduces unnecessary energy usage ........ 58
Figure 27 The majority recycles every time or almost every time they throw away trash. ........ 58
Figure 28 Carboard, bio-waste and paper are the most normally recycled materials. ........ 59
Figure 29 In general the employees find it easy to recycle at the office ........ 59
Figure 30 Energy per use of each type of cup. The energy for the disposable cups is constant as it represents only the manufacturing energy sine they are used only once and never washed. ........ 60
Figure 31 Total emissions of the company by activity ........ 66
Figure 32 Total emissions per employee by activity. Total emissions per employee are 4,92 t$CO_2$eq. ........ 67
Figure 33 The environmental contribution and intensity of the activities. ........ 68
Figure 34 Median impact from previous studies presented in chapter 3.2 ........ 69
Figure 35 Comparison of the results using three different LCA models ........ 70
Figure 36 Matrix of the financial advantage and impact on emissions in the case of reductions in the different categories ........ 81

Table 1 Why EU needs sustainable growth (European Commission 2012b) ........ 9
Table 2 Headline Indicators for Europe 2020 headline targets. The results and targets presented in the table are for the EU-28 countries (poverty and social exclusion only for EU-27) and Finland (Eurostat, 2017) ........ 10
Table 3 Approaches for greening the IT ........ 20
Table 4 Satisfying the four U-drivers will make a system serve its customers. (Watson et al. 2008, pp. 3-6) ........ 20
Table 5 Three frameworks to help identify opportunities and develop Green IT ........ 21
Table 6 Characteristics of the companies in the previous studies ........ 23
Table 7 Impact assessment further divided into five steps (Koroneos, C.J. and Koroneos, Y. 2007; AquAeTer 2011) ........ 36
Table 8 Comparison of Process LCA and IO-LCA (Hendrickson et al. 2006, p. 27; Junnila 2006b, p. 7074). ........ 41
Table 9 Energy and water consumption and unit emissions used in the study ........ 62
Table 10 Waste amounts and unit emissions ........ 63
Table 11 Commuting kilometers and emission factors ........ 63
Table 12 Inventory table. Costs presented as the percent of the costs assumed to have an environmental impact. ........ 64
Table 13 Total emissions of the company by activity ........ 66
Table 14 The carbon efficiency and intensity of Futurice. ........ 67
Table 15 Top 5 sectors for every category. Highest emission contributor to the left, decreasing impact to the right (Carnegie Mellon University Green Design Institute 2008a) ........ 70
Table 16 Suggestion for possible improvements to decrease the environmental impact of Futurice ........ 71
Table 17 Data quality estimation framework, applied from the Nordic Guidelines on Life-Cycle Assessment (Lindfors et al. 1995) ........ 72
Table 18 Quality assessment of the data collected for this study ........ 73
Table 19 Sensitivity analysis of energy consumption and unit emissions. ........ 74
Table 20 Sensitivity analysis of business travel. ........ 75

# Abbreviations

| | |
|---|---|
| $CO_2$ | Carbon dioxide |
| $CO_2eq$ | Carbon dioxide equivalent |
| COP | Conference of the parties |
| CR | Corporate responsibility |
| CSR | Corporate social responsibility |
| EFDB | Emissions factor database |
| EIO-LCA | Economic input-output – Life cycle assessment |
| EMA | Environmental management system |
| GDP | Gross domestic product |
| GHG | Greenhouse gas |
| GRI | Global Reporting |
| GWP | Global warming potential |
| IO | Input-Output |
| IPCC | Intergovernmental panel on climate change |
| ISO | International Standards Organization |
| IT | Information technologies |
| LCA | Life cycle assessment |
| LCI | Life cycle inventory |
| LCIA | Life cycle impact assessment |
| SETAC | Society of Environmental Toxicology and Chemistry |
| SME | Small and medium-sized enterprise |
| TBL | Triple bottom line |
| TOE | Tonne of oil equivalent |
| UNCED | United Nations Conference for Environment and Development |
| UNFCCC | United Nations Framework Convention on Climate Change |
| WBCSD | World Business Council for Sustainable Development |
| WRI | World Resources Institute |
| WSSD | World Summit on Sustainable Development |

# 1. Introduction

In this section background to the area of the study is given. The scope and boundary of the study is defined and the methodologies used are presented. Last the structure of the work is explained.

## 1.1 Background

"Scientific evidence for warming of the climate system is unequivocal" states the Intergovernmental Panel on Climate Change (IPCC). The increased levels of greenhouse gases (GHG), due to human activity, are with their heat-trapping nature a clear reason to the warming of the Earth. (Nasa 2017.) Even though the service sector is not traditionally per se seen as having a great environmental impact, its influence can nonetheless be neglected. In fact, it has been studied that the service sector produces a significant share of the environmental impact of our society (Rosenblum et al. 2000). It is though partly correct to assume that a shift towards a more service-oriented economy decreases the GHG emissions, because it is shown to do so when measured as GHG emission intensity per unit GDP. However, a shift to services does not mean, in itself, that the overall GHG emissions will decrease in absolute terms. The service sector in the U.S. is the largest and fastest growing sector economically and consequently the absolute emissions from the service sector will grow. (Suh, 2006.) Therefore it is important that the service sector understands its impact, responsibility and role in the attempt to reach national and global environmental goals. Environmental policy and engineering has had a tendency to focus mostly on processes that have a high concentration of pollution, either measured as emissions to different media (water, air etc.) or as quantity of emissions per produced unit. The service industry has therefore often been ignored because they seldom have a well-defined unit of production and because of their relatively low direct emissions. (Rosenblum et al. 2000.) Further the tight connection of the service sector with the output of manufacturing is often neglected. Producing services most often require some equipment and therefore a growth in the service sector naturally leads to a growth in manufacturing, increasing the emissions in that sector.

In order to improve the environmental performance, the negative environmental impacts have to be identified and measured. A framework mentioned in several guidelines for studying the environmental impact, is the life cycle assessment (LCA) framework. The LCA framework was initially designed to study direct and supply chain environmental impacts during the lifetime of a product but is subsequently also used for services and processes. A methodology, based on the LCA framework, for assessing the environmental impact is the carbon footprint. The carbon footprint methodology is broadly used by companies and organisations to examine and understand the GHG emissions occurring from products, services and processes. The most commonly accepted guideline is the GHG protocol, assembled by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). (Matthews et al. 2008, Wright et al. 2011.) In addition the term itself, carbon footprint, is widely spread and used in the world. Therefore, despite the issues and limitations related to the assessment of the carbon footprint, it can help introducing a broader understanding of the LCA concept into companies. Using the carbon footprint as a tool is better than using no tool at all. Hence, it should not be neglected as a useful tool for projects aiming at improving the environmental impact since it has been able to catch the attention of the public, policy makers and the academic community. (Finkbeiner 2009; Pandey et al. 2011; Wright et al. 2011.)

The environmental impact of service oriented companies has been discussed within the academic community since the 90's and in 1998 Graedel stressed that the impact of the service sector on the environment cannot be overlooked anymore. The LCA framework has been seen as an appropriate tool for assessing the impacts of service oriented companies and has often been cited as the most suitable framework for performing a holistic environmental assessment. (Consoli et al. 1993; Curran 1996; Kohler and Moffat 2003 in Junnila 2004, p. 191; Rosenblum et al. 2000, p. 4669,). Junnila (2004, 2006a, 2006b, 2006c, 2009) and Shrake et al. (2013) have used different LCA methods to determine the environmental impact of service oriented companies and have come to a conclusion that the division between impact categories is very similar despite different characteristics of the studied companies. In general, it is the building premises and travelling that have the biggest impact. Other categories can though, depending on the characteristic of the company, have significant impacts.

In this study, the emphasize is on the environmental impacts and the significance of the service sector, and its role in the transition to a more sustainable world. The battle against climate change has to be fought by everybody, also the service sector.

## 1.2 Objective and scope of the study

The overall objective of the master's thesis is to get an overview of the environmental impact of service oriented companies. The focus lies on impacts on climate change and the global warming potential. The aim is to find the relevant components for calculating the carbon footprint of a service oriented company and determine which activities and variables that have the biggest impact. The carbon footprint assessment will be completed with three different LCA models to compare the results and influence of different models. Suggestions on how the carbon footprint of the company could be reduced will also be given, dividing the improvements in measures requiring economic input and in measures that require behavioural change among the personnel. In combination with the suggestions the carbon efficiency and intensity per cost is briefly analysed to understand where it is most efficient to make reductions, in terms of both costs and emissions.

The central research questions are:

- What are the relevant components for calculating the carbon footprint of a service oriented company?
- Which components have the biggest impact and how could they be reduced?

The literature review will be complemented by a case study of a digital service creation company based in Finland. The company studied has several offices in Europe, this study is however limited to the Helsinki office. It was decided to only include one office to make the process as straight forward as possible, especially regarding the gathering of data. The study is focusing on using carbon footprint as a measuring instrument to determine the environmental impact, and more specifically the carbon emission equivalents, caused by the operations of the company, as measuring unit. Other environmental impacts are excluded from the study. The study covers one operational year (2016) of the company. Limitations of the scope are partly made due to the nature and objective of the master's thesis as well as both space and time limits of the work. Moreover, access to detailed data from the company's side was limited, naturally affecting the level of detail of the calculations. Therefore, this study performs a screening of the relevant and biggest impact components rather than a detailed determination of the carbon emissions from different operations.

## 1.3 Methodology

The environmental impact of a service oriented company has been studied through a literature review of previous studies and a case study. The carbon footprint of the case study company was determined by using different LCA frameworks. Overall the study could be seen as a screening LCA, as it focuses on finding the key emission components and already existing data has been used for the calculations (Junnila 2004). Further it can be called a streamlined LCA due to the limited inclusion of environmental impacts (Säynäjoki et al. 2017).

The master's thesis is mainly based on quantitative research. The data used in the case study is comprised of both primary and secondary data. The primary data has been collected through a survey study. An online questionnaire was distributed among the employees of the case comapany Futurice's Helsinki office. Secondary, internal, data was obtained from the accounting records of 2016, from discussions with Futurice and from measured quantities (energy, water, waste) by the real estate manager. The accounting records received were for both offices located in Finland. The allocation for the Helsinki office was based on the share of employees in Finland located in Helsinki. The questionnaire also provided some qualitative data, where open comment sections gave insights, thoughts, suggestions and opinions about the segments addressed in the questionnaire.

The included environmental impacts are limited to climate change and $CO_2$ equivalents, which is the definition and unit of carbon footprint in this study.

The carbon footprint was determined through two input-output LCAs (IO-LCAs) and one hybrid-LCA, in order to compare the results and impact of using different databases and methods. The ready data in the IO-databases used, are presented as $kgCO_2$/€ or $tCO_2$ /$. The monetary data in the IO-models are from 2002 respective 2005. The accounting records have been discounted to correspond to these values. One of the models uses dollars as currency and the euros have been transformed to dollars using the purchasing power parity. In the hybrid-LCA the input-output method stood for most of the inputs and the process method for the business premises (energy, waste, water) and commuting. For commuting, emission data was received from the database Lipasto traffic emissions (VTT, 2017). For energy usage emission figures were taken from an LCA calculation tool database (One click LCA 2017) and for water treatment from the service provider (HSY 2017a). Waste emissions were based on the data in WWF's climate calculator. (WWF 2017). The available data did not allow for using the process method to a greater extent. As the assessment rely heavily on budget data the hybrid-LCA can be called an IO-based hybrid analysis (Bilec et al. 2006, p. 209). The functional unit utilised is $tCO_2$ equivalents per employee (referred to as $tCO_2$eq./employee later in this paper).

## 1.4 Structure of the work

The work is divided into two main parts, the literature review and the case study. The first sections (1-4) represent the literature study. The first section (1) gives an introduction to the study and background to the topic, describes the objective and scope of the study as well as the methodologies used.

Next, in section 2, sustainable development is discussed both from an environmental, regulation and corporate view point. The aim is to explain why companies need to get involved in sustainable development. Climate change and international global actions are presented to give more reasoning to the importance of the topic and to explain the broader context. Corporate responsibility and sustainability continues to explain why companies needs to take their responsibility and what the different terms refer to. Additionally, a brief look into environmental behaviour is included.

Section 3 discusses the environmental impact of service oriented companies. As most companies use some kind of IT and as the case study company is a digital service creation company the environmental impact of IT is further discussed, and the concept of Green IT is introduced. The section includes a literature review of previous research studying the environmental impact of service oriented companies using similar methods as in this study. The results from the previous studies are compared and will give a reference to results from the case study.

Section 4 describes methods to determine the environmental impact. First the life cycle assessment framework is explained continuing with presenting the carbon footprint as a term and a method to determine the environmental impact. Then different LCA methods are described as well as the Greenhous gas protocol (often used as a guideline when performing a LCA) and other standards and guidelines.

In section 5 a summary of the literature review is given.

Section 6 describes the research design, process and methods. First the system boundary of the study is defined, and then different assessment methods used in the case study are presented.

Section 7 focuses on the case study of the digital service creation company Futurice. First the company is presented briefly after which the personnel questionnaire and its results are presented. The carbon footprint research process and values used in the assessments are then presented. The results and suggested possible improvements are presented and briefly discussed. The relationship between costs and emissions is evaluated. Further a data quality and a sensitivity analysis are performed and discussed

Section 8 The discussion section evaluates the results of the case study category wise and compares it to previous research. The relationship between emissions and costs is looked into deeper as well the suggested improvements presented in section 7. The section ends with discussing the limitations of the work and giving suggestions for future research.

Section 9 presents the final conclusions of the work.

# 2 Sustainable development

The most common and frequently quoted definition of sustainable development is found in the Brundtland Report from 1987 where The World Commission on Environment and Development (WCED) defined it as "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs". (IISD (N.D); Kleine and von Hoff 2009, p. 519.) This section presents literature concerning climate change and sustainable development and its connection to the business world.

## 2.1 Climate Change

Even though there still is some scepticism left regarding the existence of climate change there are many working for proofing its reality and effects on planet earth. Among them is IPCC (Intergovernmental panel on climate change) who presents the most advanced and well-known reports on climate change. (Ramanathan and Feng 2009, pp. 37-38.) Their fifth assessment report (AR5) of the state of knowledge about climate change was finalized in 2014 (the sixth assessment report is planned to be finalized in 2022). The synthesis report of AR5 confirms that human activities have clearly influenced the climate and that the impacts are growing. The certainty of humans being the principal cause for climate change is 95 % according to IPCC. The GHG emissions are historically high and the temperature during the last three decades has been higher than any decade before 1850. Figure 1 shows that from 1750-2011 half of the cumulative anthropogenic (human) $CO_2$ emissions can be dated back to the last 40 years. (IPCC 2014.)

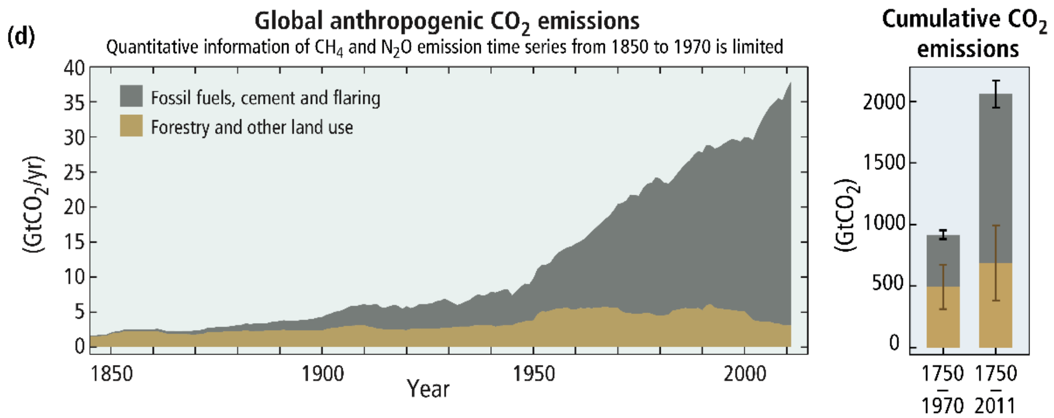


*Figure 1 Global anthropogenic $CO_2$ emissions from burning fossil fuel, cement production, flaring, forestry and other land use. The bar on the right shows these sources' cumulative $CO_2$ emissions as well as their uncertainties. (IPCC 2014, p. 3.)*

Human activity has over a relatively short period of time threatened to cause significant climate change (Karl and Trenberth 2003 cited in Chapman, 2007, p. 354). IPCC predicts that continuing the emission of GHGs will lead to an even warmer climate, implying enduring changes in the whole climate system. The probability of serious and permanent impacts on people and ecosystems will increase. (IPCC 2014, p.8.) The well documented term "global warming" refers to the Earth's measured average temperature increase caused by key GHGs in the atmosphere. The main reasons for increased amounts of GHGs are combustion of fossil fuels and changes in land use during the 20$^{th}$ century. (Weubles and Jain 2001 cited in Chapman 2007, p. 354.) The six key GHGs are: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride ($SF_6$) (WRI and WBCSD 2011, p.7).

The average temperature rise in the future depends on the amount of GHGs emitted. The total GHG concentrations expressed in $CO_2$-equivalents was in 2014 440.6 part per million (ppm). For a 50 % chance to stay within a 2°C increase compared to pre-industrial levels the concentration should not exceed 530 ppm (Figure 2). According to Figure 2 the concentration already surpasses the 50 % likelihood to keep the long-term warming below 1,5°C. If the concentration continues to increase with the same annual rate as between 2004-2013 (3,3 ppm/year) the 50 % likelihood to stay under the threshold of 2°C will be exceeded in 2043. (EEA 2016.) In other words, it can be expressed as a need to reduce the global anthropogenic GHG emissions to a level at least 50 % below the 1990 levels before 2050, in order to have a 50 % probability to stay within a 2°C increase in temperature. However, the $CO_2$ emissions from fossil fuels are over 50 % higher than the levels in 1990 and therefore cutting emissions, preferably sooner than later, is crucial to reduce the temperature rise and climate change impacts associated to that. (Plambeck 2012, p.64.)

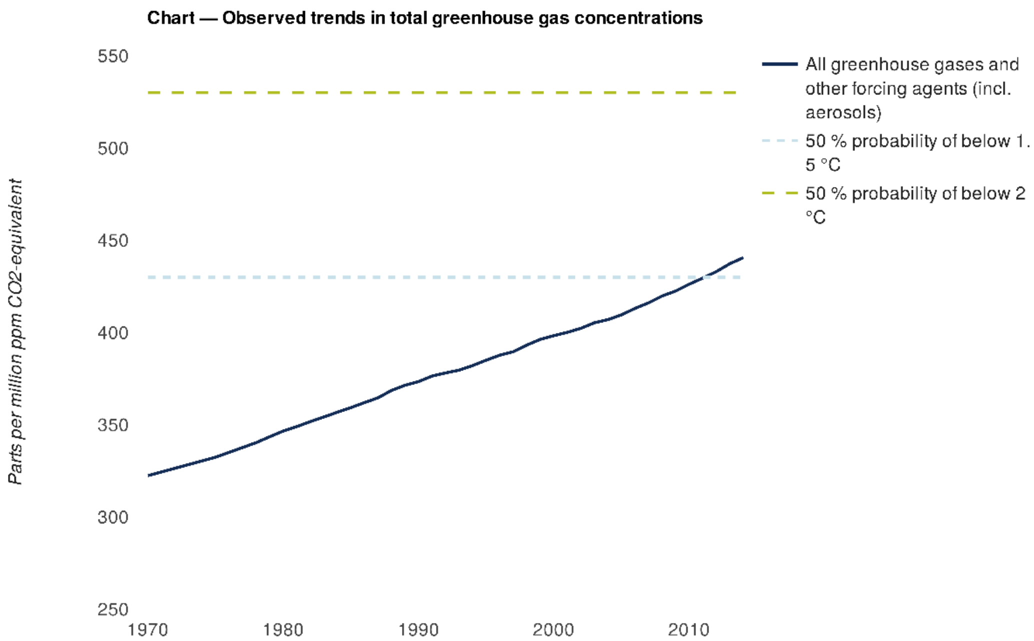


*Figure 2 For a 50 % chance for the global mean temperature to stay below a 1,5 °C respective 2 °C increase in temperature the $CO_2$-equivavlent levels should not exceed concentrations of 430 respective 530 ppm (EEA 2016).*

According to a study made by the European Geosciences Union the difference in an average temperature raise of 1,5°C or 2°C is significant. If the temperature rises 2°C instead of 1,5°C the sea-level rise, the intensity of rainstorms and the duration of heat waves will increase by a third. Further all tropical coral reefs will disappear, the fresh water reduction in the Mediterranean area would double and the impact on certain basic crops, e.g. maize and wheat, would be disproportionate. Climate scientists at NASA's Jet Propulsion Laboratory even comment the study to be too optimistic regarding the indirect and long-term (looking beyond this century) consequences of a temperature rise. The melting of ice sheets may continue long after the temperature rise has stopped due to the huge amount of heat the oceans hold, for example. They emphasize the importance of aiming to keep the temperature rise as low as possible since targeting a rise of 1,5°C may still end up with an average rise of 2°C because we are not able to control climate change with a high precision. (Silberg 2016.) The experienced effects from GHG gases today are a result of emissions from the last 100 years (Penner et al. 1991 cited in Chapman 2007, p.355). As a result of this lag and inertia some impacts of anthropogenic climate change may not be revealed, allowing for global warming to continue yet for decades after a possible stabilisation (Chapman 2007, p. 355).

Climate change is considered one of the nine planetary boundaries (PB), a framework first introduced in 2009, developed by a group of 28 scientists, presented in Figure 3. It defines the safe operating space for humanity for each key Earth System processes within which we should stay if unacceptable global human-induced environmental change is to be avoided. Unacceptable change means the risk humanity faces transitioning from the Holocene state of the planet to the Anthropocene. From a relatively stable period environmentally wise, which begun around 12 000 years ago and is the only state we know that can support current human societies, to a new era proposed to have started with the industrial revolution. (Rockström et al. 2009; Steffen et al. 2015, p.1). Steffen et al. (2015 pp.3-4) note that changes in the climate can already be seen through e.g. the increase in and the intensity, frequency and durations of heat waves, the increased rate of mass loss from the ice sheets of Greenland and Antarctic and increased drought in some parts of the world due to changes in the atmospheric circulation patterns.

Climate change will not solely have enormous social and environmental impacts, but also huge consequences economically. The financial impacts due to loss, damage and adaption will not be distributed equally across the globe. The ones often contributing the least to climate change, developing countries and low-income populations, are normally more vulnerable with a limited possibility to carry the costs. Investments in climate adaption are far from enough, especially for meeting the developing countries' needs. This huge gap should work as a reminder of the need of government actions and the important role of the private sector in order to successfully move towards low-carbon and climate-resilient economies. (Caring for Climate 2015, p. 9.)

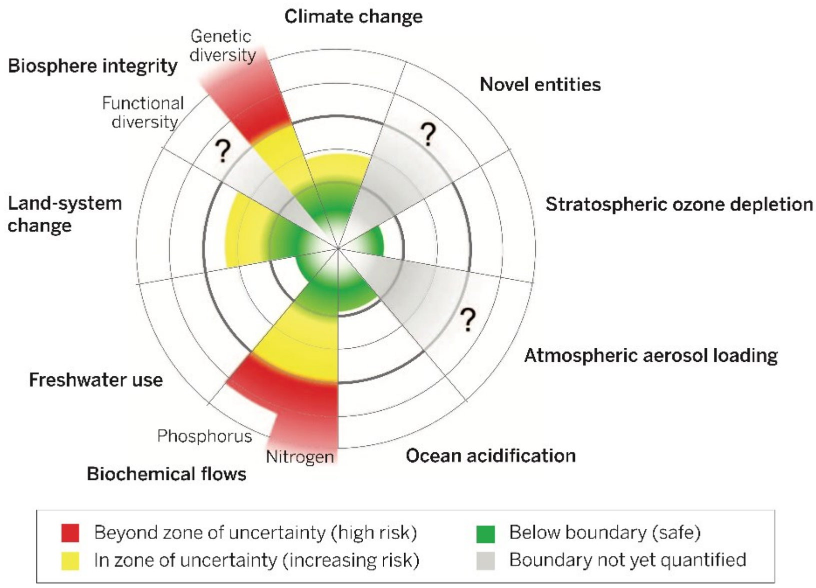


*Figure 3 Status of the PBs in 2015. The green zone is the safe operating space, yellow is the zone of uncertainty and the red is the risk-zone. The PB itself is at the inner bold circle. Three of the boundaries are already in the high risk zone and two more in the uncertainty zone. (Steffen et al. 2015)*

## 2.2 UN climate goals

UN has set 17 Sustainable Development Goals (SDGs) with the aim to transform the world. The goals go under the 2030 Agenda for Sustainable Development, adopted in 2015, which is a follow up of the Millennium Development Goals (2000-2015). Sustainable development means "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Climate change is closely incorporated in the SDGs, since actions on climate change will encourage sustainable development and vice versa; investment in sustainable development will have a positive effect on the combat towards climate change. (United Nations N.D.b) Further 12 of the 17 goals include taking actions on climate change, in addition to the direct climate action goal 13 "Take urgent action to combat climate change and its impacts".

To address the climate change issues, the Paris Agreement on climate change, was adopted at COP21 in Paris in December 2015. It entered into force in November 2016 and implementing the agreement is vital for achieving the SDGs. The Paris agreement requires that all countries take action while it keeps in mind the different circumstances of the countries. Countries will officially submit their national climate action plans, which they are obliged to implement. The agreement further require that the countries review their targets and upgrade their commitments and that they follow up their progress and report it to the public. It also functions as a sign that the governments are ready to implement the 2030 Sustainable Development Agenda. (United Nations N.D.a) The Paris agreement is the first worldwide, legally binding global climate treaty. The key target is the long-term goal of keeping the temperature raise well below 2 °C above pre-industrial levels, aiming for 1,5 °C. The importance of collaboration is emphasised and the vital role of non-party stakeholders (e.g. cities, civil society and the private sector) is recognised. The non-party stakeholders are invited to increase their efforts and support actions to reduce emissions, to build resilience to the negative effects of climate change and to promote and support both local, regional and international cooperation. (European Commission 2017c.)

The UN Global Compact call themselves the world's largest corporate sustainability initiative. Their long-term strategy is to drive awareness and action of business in a direction that supports the achievement of the SDGs by 2030. The vision of Global Compact is to "mobilize a global movement of sustainable companies and stakeholders to create the world we want". Their mission is to support companies to do responsible business according to ten principles, set by UN Global Compact, on human rights, labour, environment and anti-corruption. It also helps companies take strategic actions to promote wider societal goals, e.g. the SDGs. (United Nations Global Compact N.D.). The SDG Compass has been developed to help companies work towards the SDGs. It offers guidelines on how companies can align their strategies with the SDGs and how they can both manage and measure their contribution to the realisation of the goals. To maximise companies' contribution to the SDGs the guide presents five steps understanding the SDGs (1), defining priorities (2), setting goals (3), integrating (4), reporting and communication (5). (SDG Compass, 2015.)

## 2.3 EU Climate Action

EU Climate Action leads the efforts of the European Commission to fight climate change at both EU and international level. To their mission belongs e.g. the formulation and implementation of policies and strategies regarding the climate. They also monitor the member countries' national emissions and promote adaption measures and low-carbon technologies. (European Commission 2017d)

### 2.3.1 EU 2020 strategy

The Europe 2020 strategy is EU's ten-year strategy for jobs and growth launched in 2010. The priority of the strategy is to create conditions for smart, sustainable and inclusive growth. The priorities for strengthening growth are emphasized as a way to come over the structural weaknesses in EU's economy, establish a sustainable social market economy and improve the productivity and competitiveness. (European Commission N.D.)

Based on the strategy's three priorities (smart, sustainable and inclusive growth) EU has agreed to focus on five headline targets (employment, R&D/innovation, climate change/energy, education and poverty/social exclusion) to be reached by 2020. All five headline targets are interconnected and e.g. investments in clean technology will result in new companies and create more job opportunities while counteracting climate change. The headline target for climate change is also known as the "20/20/20" goals, as all three goals include improvements by 20 %. The three goals are:

- 20 % (or 30%, if the circumstances allow) lower GHG emissions compared to the 1990 level.
- 20 % of the energy from renewable sources.
- 20 % increase in energy efficiency.

The goals give an overview of where EU shall be regarding climate change and energy in 2020. All Member States can decide how they reach their national goals to help EU reach the overall goals. (European Commission 2011.)

To reach the goals of the five headline targets and accelerate progress, EU has identified 7 flagship initiatives under the three priority themes (smart, sustainable and inclusive growth). Most directly connected to the goals of the climate and energy headline target are the two initiatives presented under sustainable growth. (European Commission 2012a.).

Sustainable growth is defined as "promoting a more resource efficient, greener and more competitive economy" (European Commission 2010). The European Commission lists fours reasons why Europe needs to focus on sustainable growth (Table 1):

*Table 1 Why EU needs sustainable growth (European Commission 2012b)*

| | |
|---|---|
| **Over-dependency on fossil fuels** | **The dependence on oil, gas and coal makes EU vulnerable to price shocks, threatens the economic security and contributes to climate change.** |
| **Natural resources** | To help reduce the pressure that intensified competition for natural resources puts on the environment. |
| **Climate change** | To achieve the climate goals, which requires exploitation of new technologies, e.g. solar energy and carbon caption. Europe must also increase the economies' resilience to climate change and the capacity to prevent and respond to possible catastrophes. |
| **Competitiveness** | EU must improve its productivity and competitiveness and keep its lead in green solutions. Meeting the climate goals can save money in oil and gas bills and create jobs within the clean technology industry. |

The two initiatives to help boosting sustainable growth are “Resource efficient Europe” and “An industrial policy for the globalization era”. The goal of the former initiative is to support the development towards a resource-efficient and low-carbon economy. The economic growth of Europe must be disconnected from energy and resource use by reducing $CO_2$ emissions[1], promoting better energy security and by reducing the resource intensity. The latter initiative aims to create a policy that will help businesses respond to globalization, the economic crisis and the shift to a low-carbon economy. The industrial policy will support and encourage entrepreneurship, improve the business environment and cover all parts, from access to raw materials to customer service, of the increasingly international value chain. (European Commission 2010 p.6 and 2012b)

*Table 2 Headline Indicators for Europe 2020 headline targets. The results and targets presented in the table are for the EU-28 countries (poverty and social exclusion only for EU-27) and Finland (Eurostat, 2017)*

| | | 2015 | Finland 2015 | 2016 | Finland 2016 | Target (EU-28) | Target Finland |
|---|---|---|---|---|---|---|---|
| **Employment rate (Age 20-64)** | % of population between, age 20-64 | 70,1 | *72,9* | 71,1 | *73,4* | 75 % | *78 %* |
| **Gross domestic expenditure on R&D** | % of GDP | 2,03 | *2,9* | | | 3 % | *4 %* |
| **GHG emissions** | 1990 = 100 | 77,88 | *79,58* | | | ≤ 80 (reduced by 20 %) | |
| **Share of renewable energy in gross final energy consumption** | % | 16,7 | *39,3* | | | 20 % | *38 %* |
| **Primary energy consumption** | million tonnes of oil equivalent (TOE) | 1529,6 | *32* | | | ≤1483 | *35,9* |
| **Final energy consumption** | million tonnes of oil equivalent (TOE) | 1082,2 | *24,2* | | | ≤1086 | *26,7* |
| **Early leavers from education and training** | % of population aged 18-24 | 11 | *9,2* | 10,7 | *7,9* | <10 % | *<8 %* |
| **Tertiary educational attainment** | % of population aged 30-34 | 38,7 | *45,5* | 39,1 | *46,1* | ≥40 % | *≥42 %* |
| **People at risk of poverty or social exclusion** | Cumulative difference from 2008 in thousand | 1593 | *-7* | | *-14* | - 20 000 **(EU -27)** | |

The progress towards the 20/20/20 goals is regularly monitored by Eurostat. During 2014 and 2015 the European Commission completed a mid-term review of the strategy. It showed

[1] During 1990-2016, the EU economy grew by 53%. At the same time, greenhouse gas emissions decreased by 23%. This shows a possible trend of uncoupling. It is reported by the European Commission in a report ahead of the COP23 climate change summit in Bonn. (Europaportalen 2017)

that the strategy is still a suitable framework and the Commission decided to go on with the strategy. It is monitored and implemented through a process called the European Semester, an annual detailed analysis of all member countries' economic policies and efforts towards the 2020 targets. (European Commission N.D.) The five headline targets are measured by nine headline indicators, presented in Table 2 (Eurostat, 2017).

Many of the goals have been nearly met and the GHG emission target of 20 % was reached in 2014. Climate change campaigners, however, criticizes the goal of not having been tough enough in the first place. Especially since the goal won't be overshoot by 10 percentage and reach the 30 % diminish goal set to be reached if the circumstances allow. The director of Climate Action Network, Wendy Trio has said that this is a proof that EU could easily increase the climate target for 2030. (Staufenberg 2016.) The energy efficiency target is though not prone to be reached. Hungarian Green/EFA MEP Benedek Jávor points out that the primary energy savings are not projected to be higher than 17.6 %, not reaching the goal of 20 % and that a full implementation of the existing legislation should be pursued. Jávor agrees with Trio and says that EU needs to think bigger and have a higher level of ambition for 2030. Further he argues that new perspective has been brought by the COP21 Paris agreement. If EU wants to keep its lead in green solutions and the combat against climate change, the ambition levels needs to rise and the goals must be reached. (Mackay 2016.)

### 2.3.2 Future of the EU Climate Action

The climate strategy of 2020 was called "2020 climate and energy package". The 2030 goals are named "2030 climate & energy framework" and sets three key targets to be reached by 2030:

- At least 40 % lower GHG emissions compared to the 1990 level
- At least 27 % of the energy from renewable sources
- At least 27 % increase in energy efficiency.

The two first targets are binding while the last one is an indicative target that will be reviewed in 2020, possibly increasing the target to 30 %. (European Commission 2017a.)

EU has also set longer term targets for 2050, aiming to become a low-carbon economy. The European Commission's vision is to make the European economy less energy-consuming and more climate-friendly through cost-efficient methods. The milestones to reach the 80 % cut in GHG emissions compared to 1990 by 2050, are 40 % by 2030 and 60 % by 2040. All sectors have to contribute to reach the goal and the development and implementation of clean technologies have an important role in reaching the goal. The benefits, listed by the European Commission, of the EU 2050 goal to become a low-carbon society are:

- Development of clean technologies and low- or zero-carbon energy would lift the economy, stimulate growth and spur jobs
- Reduced resource use; energy, raw materials, land and water
- Diminished oil and gas dependency
- Creating health benefits e.g. due to reductions of air pollution.

The transition can be feasible and affordable but needs investments and innovations. The benefits of striving towards the 2050 climate goals corresponds with the reasoning for sustainable growth (Table 1). (European Commission 2017b.)

To be able to know if reductions of the GHG emissions are actually occurring the emissions need to be measured. Frameworks, standards and guidelines develop to support the accounting of GHG emissions are presented in section 4.

## 2.4 Sustainability within companies

Companies have a responsibility to act sustainably and this responsibility needs to be addressed. Corporate responsibility, corporate social responsibility and corporate sustainability are all terms related to the topic and ways to address the matter.

### 2.4.1 Corporate responsibility

Companies cannot anymore focus only on maximizing profit, as today's society puts pressure on the companies to take responsibility for their actions. International questionnaires demonstrate that society expects more and more from businesses. It also appears that the world has reached a higher consensus regarding the greater responsibility business has to take for environmental and social challenges. This, despite cultural and social differences between us that influence the understanding of the role that business has in the society (Rake and Grayson 2009, pp. 395-396)

Corporate responsibility (CR), also referred to as corporate social responsibility (CSR), has been discussed in academic literature since the 1950's. Tom Cannon argued in his book "Corporate Responsibility" in the early 1990's that even though the primary task of a business is to produce goods and services according to the society's needs and demands, the business and the society are mutually dependent on each other in the seeking of a stable environment. Further, the former chairman of Marks & Spencers, Lord Sieff said that "Business only contributes fully to a society if it is efficient, profitable and socially responsible". (Moir 2001, p. 16.)

In the Financial Times lexicon CR is defined as the responsibility a corporation has towards the groups and individuals it can affect. CR means "earning a licence to operate by creating value for stakeholders, including shareholders, and society" (Financial Times, N.D). There is however, still no consensus on the definition of CR. It has emerged from the stakeholder approach but later been influenced by other perspectives. The importance of the social aspect increased in the late 1980's when companies began to focus on promoting societal objectives alongside of corporate goals. Later CSR has mainly been influenced by the sustainable development paradigm and even influenced related concepts itself. (Kleine and von Hoff 2009, pp. 518-519; Kakabadse et al. 2005, pp. 278-280)

Kakabadse et al. (2005) identified several main drivers behind CSR. Among them are social contracts, legitimacy of a business, going beyond the law, sustainability, the power and influence of a business, the voluntary aspect, the multi-stakeholder framework and the context.

According to Kleine and von Hauff (2009, pp. 517-520) the current CSR policies aim to include sustainability aspects and that the term corporate sustainability might be a more suitable term. However, they also point out that the CSR concept already includes aspects of sustainable development since e.g. the European Commission in 2002 defined CSR as a concept by which social and environmental concerns are voluntarily incorporated in the companies' business operations and interactions with stakeholders.

### 2.4.2 Corporate sustainability

Eco-efficiency, a win-win situation where the efficient use of natural resources integrates economy and ecology, was the principal corporate approach towards sustainable development for many years. At the World Summit on Sustainable Development (WSSD) in 2002 it was acknowledged that the stakeholders' interests in the businesses have broadened and transformed the corporate environment. The importance of partnership between government, business and society was confirmed and WSSD also aimed at encouraging sustainable development actions. As a result, it appears that eco-efficiency alone is not anymore, as attractive and acceptable a response to the corporate sustainable development challenges as CSR. Including sustainable development in CSR is enhancing the traditional CSR concepts that are mainly focusing on tying together companies and stakeholders. (Kleine and von Hoff 2009, pp. 519-520.)

Combining the definition of sustainable development from the Brundtland report with business, Dyllick and Hockerts (2002) define corporate sustainability as meeting the needs of a company's stakeholders, both direct and indirect, without compromising the ability to meet the needs of future stakeholders. They claim that to reach this goal, companies must consider all three dimensions of sustainability, since the economic, ecological and social aspects are interdependent. Further companies need to focus on both short-term and long-term profits since corporate sustainability indicates that a company can meet the requirements of both current and future stakeholders. Within the scope of corporate sustainability companies should also contribute to sustainability in the political field of operation. (Dyllick and Hockerts 2002.)

Even though corporate sustainability may be a good term for the sustainability driven CSR approaches, as mentioned earlier, it can be argued that the more traditional CSR already includes the perception of sustainability (Kleine and von Hoff 2009, p. 529). Van Marrewijk (2003) however, suggests keeping CSR and corporate sustainability apart. CSR would be related with the social aspect of people and organizations e.g. transparency, sustainability reporting and stakeholder dialogue, while CS would concentrate on value creation, human capital and environmental management.

### 2.4.1 Responsible corporate adaption

A "Caring for Climate Report" by UN Global Compact, UNFCCC (United Nations Framework Convention on Climate Change) and UN Environment has been made in relation to COP 21 in Paris 2015 and touches the subject of responsible corporate adaption. Responsible corporate adaption can be seen as the measures companies can take to establish their risk exposure, to identify opportunities and to build resilience against climate change. The report wants to inspire companies to turn into leaders in responsible corporate adaption and through it in furthering social, environmental and economic resilience in communities. The recommendations and experiences shared in the report will also help companies work towards the SDGs (see chapter 2.2). The report emphasizes that companies' climate actions should not only focus on mitigating climate change and reducing GHGs. Measures for anticipating, preparing and adapting to changes due to climate impacts needs to be part of an effective strategy for managing and reducing the risk brought by climate change. (Caring for Climate 2015, pp.6-15.)

The report lists four main reasons for companies to get involved in corporate adaption: improving operations and competitiveness, protecting their value chain, leveraging new business opportunities and/or strengthening their corporate brand. Risk management is yet a reason to get involved. It comprises numerous business activities e.g. strategic planning, sales and marketing, human resources and CSR. Adaption strategies that are not aligned with the public efforts for adaption or that refuses to acknowledge the vulnerabilities of communities will not ensure the business to last. Companies are dependent on the well-being and resilience of the communities where they operate and sell their product and services Companies undertaking responsible corporate adaption are aware of the fact that climate change increases the interdependencies between business, government and civil society and they put effort on considering how companies' can and should help communities to adapt. (Caring for Climate 2015, pp.6-15.)

CSR is a very rich but complex concept. It is context dependent and sensitive to environmental, organizational and individual particularities. Therefore, it must be recognized as a multi-layered, multi-stakeholder and cross-disciplinary approach that depending on the situation may require a different focus. (von Hoff and Kleine 2009 pp. 518-519; Kakabadse et al. 2005 p. 286.)

## 2.5 Enhancing environmental responsible behaviour

"Even though the effect of an individual office worker is small, the effect of all employees on the environment and the organization's economy is great" concludes Koivisto (2008, p. 134-135) in her doctoral dissertation "Factors influencing environmentally responsible behaviour in the Finnish service sector".

Koivisto (2008) argues that "it can hardly be denied that sustainable development requires substantial changes at the level of individual human behaviour". Both previous research (Uusitalo 1991, Meadows et al. 1993, Järvelä et al.1996a, Widegren 1998, Bratt 1999a, Ebroe et al. 1999, Nordlund et al. 2002, Do Valle et al. 2004 in Koivisto 2008, p. 16, p.48) and Koivisto argue that sustainability cannot however be achieved before people accept their responsibility for their own behaviour and the environmental consequences of that. Employees in the service sector may not realise that their actions at work have environmental consequences and that they have an as important role in environmental protection as the industry sector. The problem is when people believe that their individual actions are insignificant. People who think that environmental problems can be solved by science and technology are not as likely to see the need for individual action as optimistic people who believe in individual efforts (Blake 2001 in Koivisto 2008, p. 63). It has been found that people with a cooperative value orientation put more weight in the collective consequences of their own behaviour. These kinds of people find, that as members of society, it is of mutual interest that most people embrace an environmentally friendly lifestyle. (Widegren 1998, Nordlund et al. 2002 in Koivisto 2008, p. 63-64). Koivisto (2008, p. 122) found that subjective norms, e.g. social pressure from colleagues, can make affect people to behave more environmentally responsible.

"You can't order people to change" said Paul O'Neill, a former CEO at Alcoa who increased the net income of the company 5 times in around 10 years. To turn the company's downshifting results up again he identified keystone habits among the employees and believed that slowly changing them would lead to a chain reaction through the company. The idea is that when changing the habits that matter the most it will disrupt and remake other patterns. (Duhigg 2013, pp.97-101.)

Duhigg (2013) describes the golden rule for changing habits: keep the cue, change the routine and keep the reward. A simple example would be to stop snacking. If you actually snack to interrupt boredom and not to satisfy hunger the reward is actually to get a small break, not to get something to eat. The routine could hence be changed to e.g. a quick walk or a few minutes on the internet. This gives the same interruption without including eating. In the case of Alcoa, O'Neill identified a simple cue: a work injury. He introduced a routine in any case an employee got injured: it had to be reported to him within 24 hours together with a plan that would ensure that the injury would never happen again. The reward was that only those embracing the system could get promoted. This change of habit improved communication within the company, decreased the number of injuries, increased productivity, decreased cost and improved the quality. (Duhigg 2013, pp. 60-109)

Knowledge about the main drivers behind changes in people's environmental and economic behaviours is needed for a company to motivate its employee's to more environmentally friendly behaviour. A key driver for environmentally responsible behaviour is environmental sensitivity. It means the ability to sense and observe the surrounding environment and possible changes in it. Earlier researchers show that environmental responsible behaviour is not driven by a specific factor, rather it is a sum of several factors regarding situations, motivation, attitude, knowledge and background. A summary of variables that predict environmental responsible behaviours is illustrated in Figure 4. (Maloney et al. 1975, Gamba et al. 1994, 1995, De Young 1996, Cottrell et al. 1997, Bratt 1999a, Olli et al. 2001, LaRoche et al. 2002, Do Valle et al. 2004, Barr et al. 2005 in Koivisto 2008, p. 17).

One of Koivisto's (2008) three main findings is that purely knowledge about environmental problems and their causes does not bring out environmentally responsible behaviour. It is essential to be motivated and also have knowledge about what needs to be done (Zimmermann 1996, Kilbourne et al. 2005 in Koivisto 2008, p. 59; Koivisto 2008, p.127). Secondly Koivisto found that environmental training improves the employee's knowledge of how to act in an environmentally responsible way and of the effects of environmental responsible behaviour on the environment and economy. Thirdly, the results of Koivisto's research propose that there should be regular repetition of environmental training. Methods

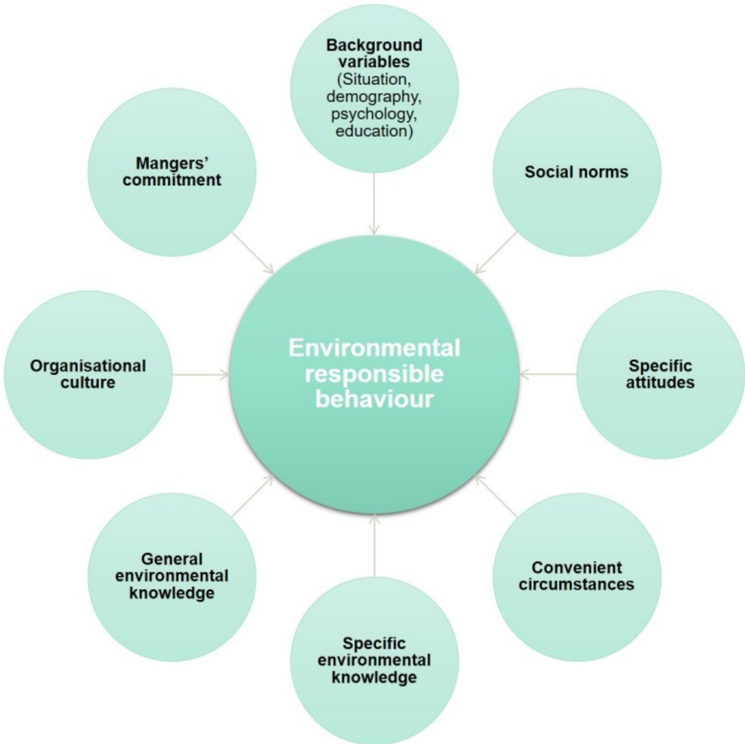


*Figure 4 Factors that influence environmentally responsible behaviour (Koivisto 2008, pp. 71, 140)*

for education employees about environmental issues are e.g. internal and external training, team work and mentor guidance (Huhtinen 2001, Bryson et al. 2006 in Koivisto 2008, p. 62). Koivisto found in her study that the specific attitude, among those who have had the opportunity to take part in environmental training (regardless of if they actually participated or not), is more responsible than those who have not have the opportunity to participate in training. Those who had participated in training were more aware of their own impact, responsibility and role associated with the whole company's environmental behaviour than those who didn't take part in the training. Simply by organising training the employer expresses that the company values environmental friendly behaviour, which already has shown to increase responsible behaviour.

Further the environmental behaviour and the roles of the directors in a company are crucial. The employers task is to encourage employees towards environmentally responsible behaviour and make it possible. This can be done by integrating management systems and environmental issues, possibly establishing an environmental management system (EMS). The commitment of employees towards environmental issues depends on the culture of the company. Employees will not start to act more environmentally responsible if directors are not contributing to the employees' environmental behaviour. Showing appreciation of employees' own environmental efforts can engage employees in their environmental learning process. (Huhtinen 2001, Bryson et al. 2006, Rasmus 2001 in Koivisto 2008, pp. 61-62; Koivisto 2008, p. 18.)

In the end, the greening of a company depends on all stakeholders; employees, customers, NGOs, owners and authorities, and their aims, values, beliefs and requirements (Koivisto 2008, p. 70). For a company to influence and support employees' attitudes towards environmental responsible behaviour important means are: clear target setting, environmental education and training, attitudes, situational variables, motivation coming from other people, encouraging examples from leaders, enhancing acceptance of environmental friendly behaviour within the company, favourable circumstances, feedback and rewards. Instructions and step-by-step guidance can help to improve certain behaviours. (De Young 1996, Moisander et al. 2001, Ramus 2001, McMakin et al. 2002, Rasmus 2001, Barr et al. 2005 in Koivisto 2008 p. 133; Koivisto 2008, p. 134)

Understanding and changing behaviour is essential to create a more environmentally friendly world. Only relying on more efficient equipment and processes won't be enough to solve all environmental problems (Koivisto 2008, p. 125) and reach the global climate goals, which are vital for keeping our planet habitable. As the root to environmental crises is human behaviour, the actions and behaviour of individuals is playing an ever more critical role (Koivisto 2008, p. 125). Companies need to understand their responsibility in turning employees' behaviour in a more environmental friendly direction and their possibility to form more environmentally aware citizens.

# 3 Environmental impact of service oriented companies

The service sector is often seen as clean industry and therefore they in general pay little attention to their environmental impact (Junnila 2006a, p.114). The environmental impact of service oriented companies is in fact low compared to the manufacturing industry when measured per dollar of output. The service sector in the U.S however, has a bigger share of the economy and the monetary output is twice the amount of the manufacturing sector. This means that even though the environmental emissions and waste directly generated by the service sector is low per dollar of output the overall emissions, waste generation and energy consumption is significant because of the large share of GDP. Of the 1996 U.S GDP 60-80% was associated with the service sector, depending on which services that are included. (Rosenblum et al. 2000, p. 4669.) In the Western countries around 70 % of all workplaces and of the gross national product are in the service industries according to Junnila (2006a) and the importance of this sector is constantly growing.

Suh (2006) concludes that even though GHG emissions per unit GDP will decrease by shifting towards a more service oriented economy, that will not in itself lead to a decrease in the aggregated GHG emissions. Suh means that the fact that services are connected to manufacturing outputs often is neglected. Service oriented companies also use different equipment, e.g. computers, office furniture and supplies, etc. A growth in the service sector may very well also increase the output in the manufacturing sector. Even though the relative share of the manufacturing sector gradually has been surpassed by services, the production of manufactured goods in absolute term has for the past four decades followed an upward trend. Due to this, an actual reduction of GHG emissions in absolute terms will not be achieved unless services become independent of GHG emission intensive products. (Suh 2006, p. 6560.)

So, the absolute environmental impact of service oriented companies can be significant and the potential of reducing the environmental impact of the sector has been estimated to be substantial (Junnila 2006a, p. 114). Rosenblum et al. (2000, p. 4669) lists four ways in which the service sector can influence environmental performance of different stakeholders; by:

- Demanding more environmentally conscious products and services from suppliers
- Reducing resource inputs in their own operations e.g. by cutting business travel or by implementing energy efficiency programs
- Educating consumers about the relative qualities of different products and the importance of their choices (especially within retail sales)
- Reducing the resource use of consumers by using more environmentally beneficial services and activities (e.g. using teleconference services instead of business travel).

## 3.1 The environmental impact of IT

The service sector does not produce physical products itself, but is yet highly dependent on manufactured goods. Among them a great deal of goods related to information technologies (IT). The use of IT has grown immensely in many different areas and the adoption of IT is widespread (Murugesan 2008, p. 24; Jenkin et al. 2011 p.17). The impact on the environment from increased utilisation of IT is however not black and white. There are both positive and negative aspects to it. On one hand IT can be seen as causing environmental problems, on the other hand as being a part of the solution. (Bohas and Poussing 2016, p. 241.) The negative impacts are not always realised, even though the production, use and disposal of computers and other IT infrastructure have an influence on the environment. IT consumes a significant amount of energy, causing carbon emissions. The production of the hardware uses in addition to energy also raw materials, chemicals, water and creates hazardous waste. For example, the continuous increase of internet and web applications has led to a rapid growth of the number of data centres and between 2000 and 2005 the aggregated electricity use in data centres doubled. Further a lot of electronic equipment outdates fast and is discarded after only two to three years, ending up in landfills. As they contain toxic materials they will pollute the earth and contaminate ground water. Hence the rising amount of IT infrastructure and its fast circulation makes its environmental impact non-negligible. (Bohas and Poussing 2016, p.241; Albertao 2012, pp. 63-67; Jenkin et al. 2011, pp.17-18; Murugesan 2008, p. 25-28; Yi and Thomas 2007, p. 847; Berkhout and Hertin 2004, p. 905.)

On the other side, IT plays an important role in sharing knowledge and awareness about environmental issues or in enabling understanding of environmental processes and responses to identified problems. Thus, there are negative impacts that can be traced back to the use of IT but it also provides the instruments for better understanding those and other environmental impacts. (Berkhout and Hertin 2004, p. 906). Other environmental benefits of IT are linked to increased efficiency, transparency and transaction speed, for instance. An example is the substitution of a transatlantic business flight, using around 40 000 litres of fuel on average, with teleconferencing. (Yi and Thomas 2007, p. 847).

Plepys (2002) discusses the grey side of IT through the rebound effect. He means that the use of IT can boost consumerism and gives some examples of environmentally adverse behavioural changes. An example is the dramatic changes IT has made in the way we buy products. Buying online with basically one click makes finding, comparing and buying goods and services extremely easy. It creates near to perfect market conditions pushing competition, which reduces prices and increases demand. So even though e-commerce gives great potential for companies to reduce their environmental impact through optimising logistics, reduce overproduction, manufacturing waste, storage etc. at the same time it tends to accelerate the production and delivery of goods which is increasing courier and packaging services and to allow customized products that may lead to nonstandard packages and reduced vehicle load efficiency. Plepys (2002) concludes that the use of IT has potential to decouple economic growth from environmental contamination if potential rebound effects are taken into consideration.

Human behaviour becomes a very important factor as much of the environmental impacts of IT depend on how the IT applications are used. The use of IT will not automatically lead to a more environmentally friendly future, yet it offers many opportunities for developing more sustainable solutions. There is a need for forward-looking IT-specific policies and regulations that endorse technologies promoting sustainable growth in an efficient way and that encourage environmentally beneficial areas of IT application. They will play a crucial role if the opportunities for IT to support sustainable development are to be seized. Policy involvement is often necessary when the market fails to address environmental issues. (Hilty et al. 2006, pp.1625-1628; Berkhout and Hertin 2004, pp.904-916; Plepys 2002, pp. 518-521.)

### 3.1.1 Green IT

The positive environmental effects of using IT can be achieved by practicing Green IT, which refers to solutions, initiatives and programs that take into account environmental sustainability directly or indirectly. It means using IT resources in an energy-efficient and cost-effective way, minimizing the impact on the environment. (Bohas and Poussing, 2016, p.240; Bose and Luo, 2011, p.38; Jenkin et al., 2011, pp.17-18; Murugesan, 2008, p. 25-26).

Ruth (2011, pp. 207-208) lists four important sectors where Green IT can save energy and fuel cost and reduce $CO_2$ emissions: smart grids, smart buildings, road transportation efficiency and travel substitution. Other positive Green IT improvements according to Ruth can be achieved through: rating systems (e.g. EPEAT and Energy Star), energy efficient data centres, virtualization (efficient management of servers, virtual machines, better automation of data centre tasks etc.), remote working, cloud computing (storage and processing in the cloud), power management technologies (e.g. energy-saving mode in computers) and dematerialization (mail, movies, books, newspaper etc. online). Further he mentions two studies that have estimated the potential worldwide $CO_2$ reduction to be 5,6-7,8 gigatons thanks to Green IT solutions.

Steigerwald and Agrawala (2012, pp.39-42, 59-60) lifts up the importance of green software and the fact that the behaviour of the software plays a significant role in whether built in energy saving features in platforms (combinations of hardware, software and other technologies that makes the software to run) are effective or not. A poorly structured or power-ineffective software can foul all power management benefits and energy saving features built into a hardware. Energy efficiency within the computing industry is central to achieve increased battery life of mobile platforms and reduced energy expenses of desktops, server platforms and data centres.

Green IT can be further divided into information technology and information systems. Technology examples are: improving the energy efficiency of data centres, using virtualization software to run several operating systems on one server or reducing waste from outdated equipment. Examples of green information systems are: systems beyond telecommunication that enables remote meetings, e.g. group documentation and environmental information systems that track and monitor environmental variables like waste, emissions, water consumption and carbon footprints to be able to manage them more effectively. Green information systems are seen to have greater potential than only technology to indirectly decrease environmental impacts, because it focuses on entire systems. (Jenkin et al, 2011, p.18; Watson et al., 2008, pp.2-3).

#### *3.1.1.1 Greening of IT*

Murugesan (2008) lists three approaches a company can take and freely combine, to green its information technology and systems. The approaches are presented in Table 3.

Frameworks can help to approach problems, brainstorm solutions and plan the implementation of innovations. Watson et al. (2008) presents fours frameworks that can be used to identify Green IT and sustainable business process opportunities and help with the development of Green IT. One of the key elements for successful IT that drives people to a more environmentally friendly direction, is to satisfy the four information drivers: ubiquity (e.g. mobile phones), uniqueness (e.g. navigation systems), unison (e.g. synced calendars) and universal services (e.g. smart phones). It is people's addiction to information that makes them seek systems that fulfil these four U-figures. Table 4 gives examples of how they contribute towards a sustainable society.

The other three frameworks to help identify Green IT opportunities are: sustainability options by action level, strategic alignment and ecological thinking. They are presented in Green IT is not only directly green itself but can also be indirectly green by creating, supporting and leveraging other green approaches and environmental initiatives. Green IT can offer different tools e.g. software for analysing and simulating environmental impact and risk management, platforms for eco-management or emission trading, tools for monitoring and reporting energy consumption and GHG emissions or tools and systems for urban environmental planning. In addition, it can help raise awareness among IT professionals, businesses and the public about environmental issues. Through web pages, blogs, social media and interactive simulations of an activity's impact on the environment IT could assist in engaging communities and groups in participatory decision making and support educational and green encouragement campaigns. (Murugesan 2008, pp. 31-33.)

Table 5. To promote companies to think about organisational sustainability, a strategic alignment of IT with the company as well as incorporation of sustainability in the corporate strategy is necessary. In addition, corporate sustainability and Green IT naturally involves ecological thinking.

*Table 3 Approaches for greening the IT*

| Tactical incremental approach | Strategic alignment of IT | Ecological thinking |
|---|---|---|
| **Preserving the existing IT while taking simple measures towards modest green goals** | Performing an audit of the existing IT infrastructure and its use from an environmental perspective. An extensive plan for greening the IT is drawn and new initiatives are implemented. | Builds on the strategic approach, going further by taking additional measures. |
| **Should be seen as short-term goals working towards greater measures on the long-term.** | Considers cost efficiency and a reduced carbon footprint but also branding, image and marketing. | A company can look beyond the company limits and encourage its personnel to move towards Green IT at home by e.g. offering computer recycling provision or provide them with a free power management software. |
| **E.g. reducing energy consumption by implementing power management and using energy efficient light bulbs.** | E.g. replacing old computing systems with environmental friendly and energy-efficient systems. | E.g. adopting a carbon offset policy that can include planting trees, buying carbon credits or using renewable energy. |

*Table 4 Satisfying the four U-drivers will make a system serve its customers. (Watson et al. 2008, pp. 3-6)*

| U-figure | Ubiquity | Uniqueness | Unison | Universality |
|---|---|---|---|---|
| **Contribution to sustainability** | Increase the utilization of physical assets through IT | Match available resources to people's needs. | IT can make actions simple and familiar by providing interfaces easy to use. | IT can help with the transition between physical systems |
| **Example(s)** | Increase use of public transport: Know the location of the nearest bus stop, one's distance from it and the arrival time of next bus. | Using GPS to locate one self.<br>Public transport route planning system for getting from place A to place B. | Using ATM's are familiar procedures that are very similar across the world. | The metric system (SI) that makes trading easier.<br>ATM networks that make it possible to get local currency despite of home country currency. |

Green IT is not only directly green itself but can also be indirectly green by creating, supporting and leveraging other green approaches and environmental initiatives. Green IT can offer different tools e.g. software for analysing and simulating environmental impact and risk management, platforms for eco-management or emission trading, tools for monitoring and reporting energy consumption and GHG emissions or tools and systems for urban environmental planning. In addition, it can help raise awareness among IT professionals, businesses and the public about environmental issues. Through web pages, blogs, social media and interactive simulations of an activity's impact on the environment IT could assist in engaging communities and groups in participatory decision making and support educational and green encouragement campaigns. (Murugesan 2008, pp. 31-33.)

*Table 5 Three frameworks to help identify opportunities and develop Green IT*

| Sustainability options by action level | Strategic alignment of IT | Ecological thinking |
|---|---|---|
| **Pollution prevention: Decrease waste and emission streams** | Aggregation:<br>Combining activities into optimal and efficient units to reduce costs, emissions and waste | Eco-efficiency:<br>Produce satisfying goods and services while reducing ecological impacts and resource intensity through the life-cycle, at least to a level within earth's carrying capacity |
| **Product management: Pollution reduction and life cycle thinking, recycling, reuse** | Adaption:<br>Adopting explicit environmental initiatives that will decrease emissions and waste in the locations where the organisation is operating | Eco-equity:<br>Distributing the natural resources fairly between both current and future generations |
| **The use of clean technology:**<br>**Using technology that does not create harmful emissions or waste** | Arbitrage:<br>Selecting the best alternatives, e.g. choosing the least polluting retailers to get the most environmentally friendly IT product | Eco-effectiveness:<br>End practices that lead to ecological degradation and move towards a circular economy where waste from one process becomes inputs in another |

## 3.2 Comparison of studies on the carbon footprint of service oriented companies

Junnila (2004, 2006a, 2006b, 2006c, 2009) and Shrake et al. (2013) have used the LCA framework to determine the environmental impact of selected service oriented companies. Figure 5 compares the LCAs completed and gives an overview of the impact distribution between emission categories in different companies. The results are further discussed in the following chapters. The assessments are not only focusing on the impact service oriented companies have on climate change (kg $CO_2$ equiv.) but also on acidification (kg $SO_2$ equiv.), summer smog (kg $C_2H_4$ equiv.), eutrophication (kg $PO_4$ equiv.), heavy metals (g Pb equiv.) etc. This work is however limited to study the carbon footprint and hence only the impact on climate change, expressed in $CO_2$ equivalents, is discussed here. It is though important to keep in mind that companies are not only having an impact on climate change, but on other environmental and health aspects as well.

### 3.2.1 Presenting the cases and LCAs

The grouping of the results differs somewhat in the original studies but not to the extent that it would prevent a comparison. However, it should be pointed out that the difference in grouping naturally impacts the distribution of emissions. One of the biggest distinctions is that in the cases 2-7 and 10-13 (Junnila 2006a, 2009) business travel is separated from commuting while in the other assessments they are combined into one category (here business travel). Commuting is included even though it is not directly a part of a company's operations. It is though very closely related to the work process and therefore, it is often voluntarily included in the environmental objectives. (Junnila 2004, p. 191). Another big distinction in the grouping is in the cases 2-6 (Junnila 2004) compared to the others. In these cases, the processes of the five companies were divided into tangible and intangible expenses. The tangible expenses included materials, energy and services with material or energy inputs. The intangible represented wages, social expenses, software leasing and non-material services. The intangible expenses were assumed to not have any environmental impact by nature and therefor these cases lack input in the "purchased services" category. Moreover, the applied LCA methods differ between and within the studies. It is especially interesting to compare the LCAs number 8 and 9 (Junnila 2006b), which demonstrate an empirical comparison of using the process (PRO-) and IO-LCA methods (see chapter 4.3 for

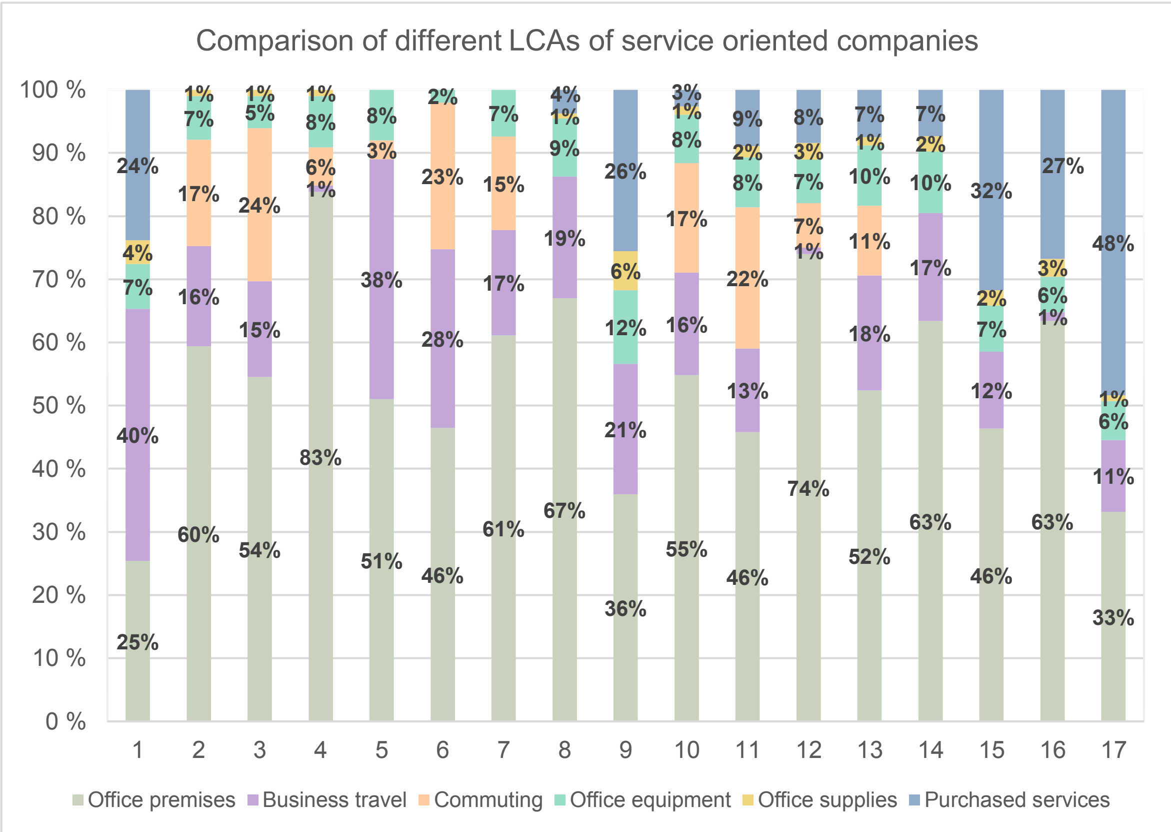


*Figure 5 Comparison of LCAs made for service oriented companies, expressed in percentages of total emissions. From left to right: (1) Shrake et al. (2013) hybrid-LCA of a company situated in the U.S., (2-6) Junnila (2004) hybrid-LCA of five companies situated in Finland, (7) Junnila (2006a) hybrid-LCA, creating a base case based on six companies situated in Finland and one in the U.S., (8) Junnila (2006b) PRO-LCA of a company situated in Finland, (9) Junnila (2006b) IO-LCA for same company as case 8, (10-13) Junnila (2006c) hybrid-LCA of the companies based in Finland and one in the U.S, (14-17) Junnila (2009) process based hybrid-LCA of the same companies as in cases 10-13. The scope of all the LCAs covers one-year operation of the service sector companies studied.*

further information about LCA calculation methods) for a consulting and engineering company. The comparison is further discussed in the chapter 3.2.3 Empirical comparison of different LCA methods.

The cases 10-13 (Junnila 2006c) and 14-17 (Junnila 2009) examine the same companies, however the former study uses the hybrid-LCA method and the latter is a process based LCA only using monetary based calculation for the purchased services. Further the process based LCA is considering added supply chain stages but is not taking into account commuting while the former is, therefore they are not completely comparable as hybrid vs. process based assessments. Case 7, representing the base created by Junnila (2006a), is based on 6 companies. 5 of these companies are the same companies used in an earlier study by Junnila (2004), here cases 2-6. The characteristics of the cases found in the previous studies are presented in Table 6.

*Table 6 Characteristics of the companies in the previous studies*

| Case | Number of employees | Location | Field | Operation area | Office space per employee | Business travel / Commuting [km/pers./a] |
|---|---|---|---|---|---|---|
| 1 | 90 | Chicago | Civil and environmental engineering and consulting | Regional | | |
| 2 & 7 | *Varies between 10-435* | Finland | Banking, consulting or ICT | Mainly domestic, also European and global markets | 25 | 6060 / 7936 |
| 3 & 7 | | Finland | | Mainly domestic, also European and global markets | 21 | 3476 / 9891 |
| 4 & 7 | | Finland | | Mainly regional, some national and Scandinavian markets | 23 | 840 / 4465 |
| 5 & 7 | | Finland | | Mainly Scandinavia, also other European countires | 33 | 24 519 / 9229 |
| 6 & 7 | | Finland | | Domestic, European and global markets | 29 | 5528 / 8113 |
| 7 | | U.S. | | Mainly domestic and European markets | 29 | 18 470 / 10 200 |
| 8 & 9 | 150 | Finland | Consulting and engineering company | Mainly Europe, some Asian, South American and North American markets | | |
| 10 & 14 | 132 | Finland | Engineering and consulting | Mainly domestic, also European markets | | |
| 11 & 15 | 45 | Finland | Consulting | Domestic, European and global markets | | |
| 12 & 16 | 160 | Finland | Banking | Mainly domestic | | |
| 13 & 17 | 26 | U.S. | Facility management | North America and global markets | | |

### 3.2.2 Comparison by impact category

In this chapter, the LCAs performed and presented in the last chapter are compared by category to give a deeper understanding of the results. The text refers to both Figure 5 showing the distribution of the emission categories' influence for the case companies, as well as the category specific Figure 6 to Figure 10 Emissions caused by purchased services for cases 1 and 8-17. In the remaining cases, the impact from purchased services was left out. The median of the cases is also presented in the figure. showing the absolute emission as $kgCO_2eq$. per employee. High impact in one category naturally decreases the relative contribution in the other categories. That is why the results are as well presented as absolute values in order to see the differences between actual emission among the companies and not only the distinct percental distributions. The total emissions per employee vary between 3,1 and 21 $tCO^2eq$. The average impact is 7,4 and the median is 5,9 $tCO^2eq$./employee.

#### 3.2.2.1 Office premises

In most cases office premises account for the majority of the emissions (25-83 %), with the exception of the cases 1, 6 and 17. Electricity and heating are normally creating over half of the emission in this category. The rest consists of emissions from construction, waste management, water usage, maintenance and other operations that are directly linked to the premises and its daily operations. The environmental impact from energy is further discussed in chapter 3.2.4 and waste management and recycling are further discussed in chapter 3.2.6. In most cases electricity usage caused most of the office premises impacts, though varying depending on the electricity use for the building and the environmental profile of the used electricity. For example, the emissions caused by the electricity used by case 6 is close to 0 % because the energy used is mainly produced by nuclear plants, thus leading to heating representing the biggest part of the category. Case 4 has the highest share of emissions caused by the office premises, 83 % (Figure 5). The case company mainly uses energy produced primarily by coal and heavy oil fuels. Case 4, however, does not have the highest absolute emissions in this category. Seen from Figure 6 the highest value, 7000 $kgCO_2eq$. per employee is for the company represented by cases 13 and 17 (hybrid vs. expanded process). The lowest value is 1426 $kgCO_2eq$./per employee by case 6 and the median impact per employee is 2922 $kgCO_2$.

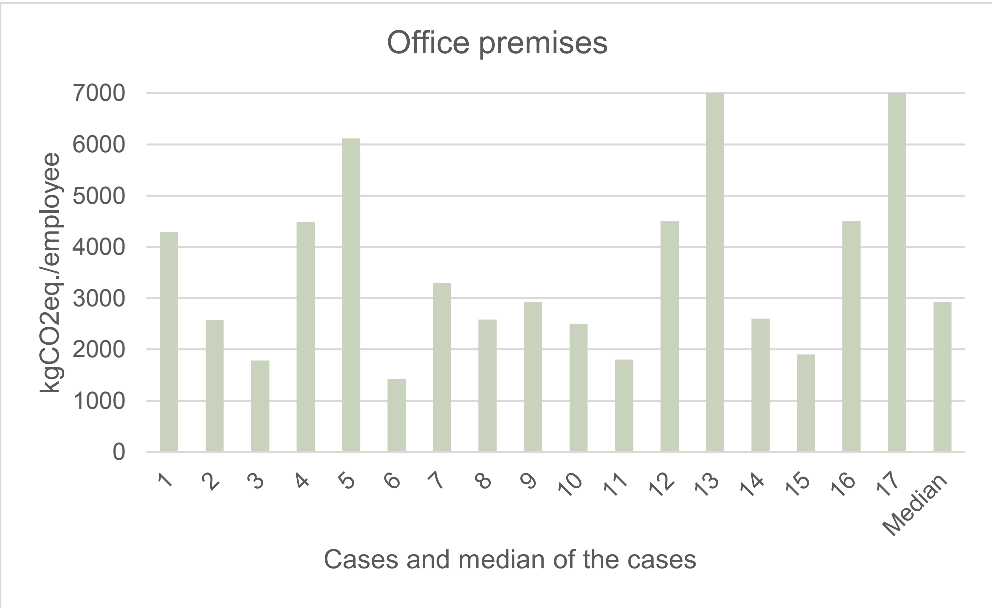


*Figure 6 Emissions caused by the office premises for cases 1-17. The median of all the cases is also presented in the figure.*

#### 3.2.2.2 Business travel and commuting

In most cases business travel and commuting represent the second highest impact category. The variance between the results is high though, reaching from 1 to 41% of the total emissions. Figure 7 Emissions caused by business travel (purple) and commuting (orange) for cases 1-17. The median of all the cases is also presented in the figure. Shrake et al. (2013)

explains the high results in case 1 by the location of the office and the model and use of company cars. The company is located in a suburban setting in the U.S. where the infrastructure is designed for personal vehicles and the business requires employees to travel to the customer's office. Most of the company's cars are light duty trucks or SUVs (Sport Utility Vehicles) since majority of the driving of the engineering consults includes driving on construction sites. Further it was reviled that the average reported roundtrip commuting distance was 64km, with no use of carpooling and less than 1 % using public transport. Therefore, the business travel (including commuting) category stand for most of the emissions in case 1 and it has also the highest absolute emissions of the compared companies in this category. Junnila (2004) explains the low impact of commuting and business travel in case 4 by the fact that it has the lowest commuting distances of the cases in the study (cases 2-6) and most commuting is done by train. In addition, the amount of business travel is very low. Case 5 has good rail connections actively used by the employees (80 % of the commuting done by public transport, rail being the principal choice) but business travel has a high share as one of the company's major customers is located in another country increasing the flight numbers and distances. In almost all cases where business travel is further analysed (Junnila 2004, 2006b, 2006c) flights account for the majority of the emissions, with a few exceptions (case 4 and 12) where passenger cars formed the biggest part of the business travel category. In cases 10-13 (Junnila 2006c) the high impact from commuting is explained by the extensive use of private cars. The low impact from business travel in case 12 and 16 (same company, different studies) can be explained by the characteristics of the company. It is a Finnish retail banking organisation mostly involved in Finnish operations.

The median impact caused by business travel and commuting is 740 kg$CO_2$eq./employee, with the highest impact caused by case 1 emitting 6740 kg$CO_2$eq./employee and the lowest impact by case 4 emitting only 54 kg$CO_2$eq./employee. The environmental impact of transportation is further discussed in chapter 3.2.5.

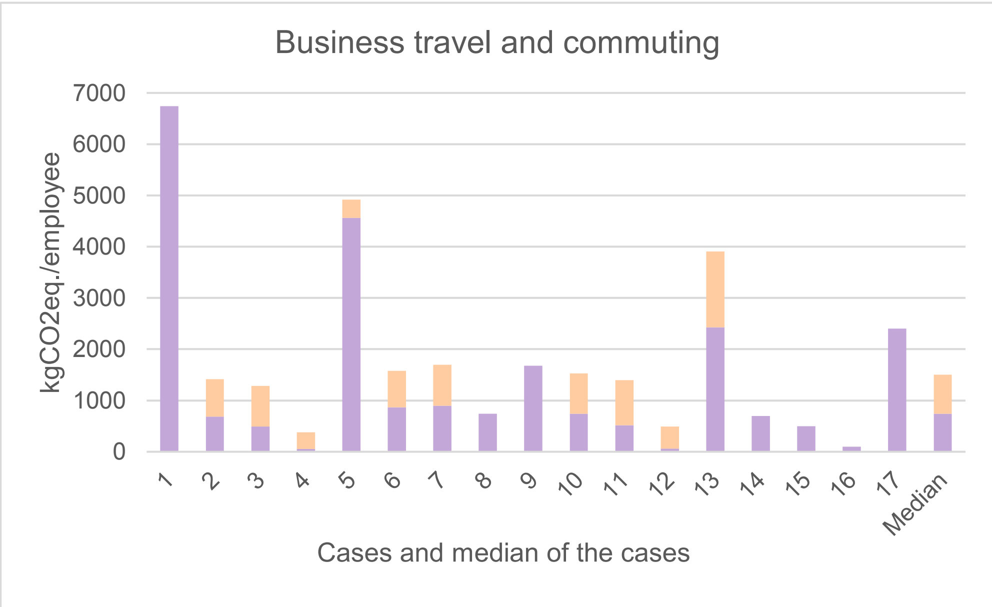


*Figure 7 Emissions caused by business travel (purple) and commuting (orange) for cases 1-17. The median of all the cases is also presented in the figure.*

### 3.2.2.3 Office equipment and office supplies

The overall impact from office equipment and office supplies is small (1-12%) compared to the other impact categories. The office equipment causes higher absolute emissions, with a maximum of 1300 $kgCO_2eq$. per employee for case 17 and a minimum of 62 $kgCO_2eq$. per employee for case 6. The biggest impact in the office supplies category is 638 $kgCO_2eq$. per employee by case 1 and the lowest impact by case 8 with only 30 $kgCO_2eq$. per employee. The median impact is 400 for office equipment and 100 for office supplies. The results are presented in Figure 8 and Figure 9.

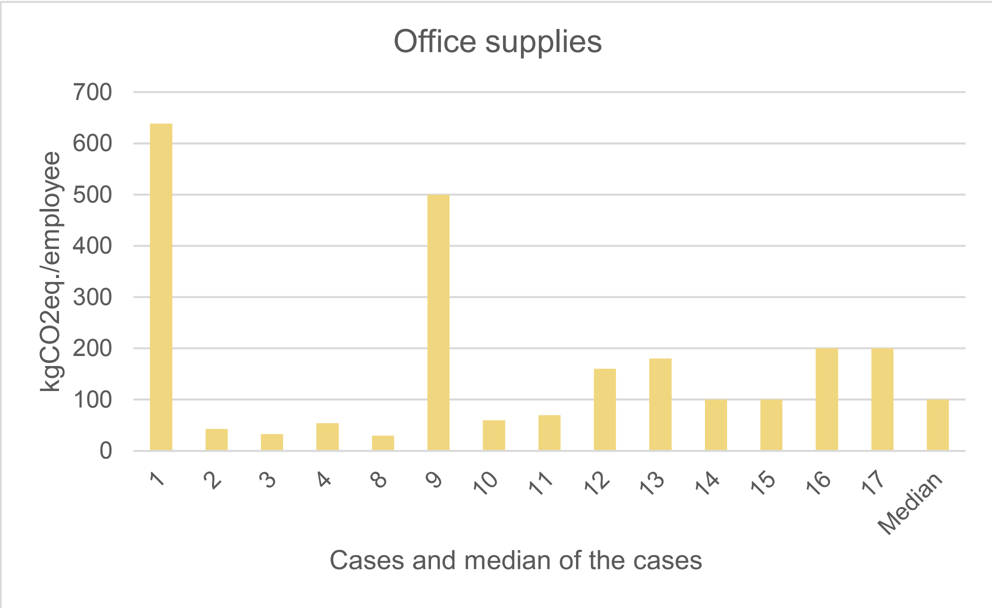


*Figure 8 Emissions caused by office supplies for cases 1-4 and 8-17. In cases 5-7 the impact from office supplies was 0. The median of all the cases is also presented in the figure.*

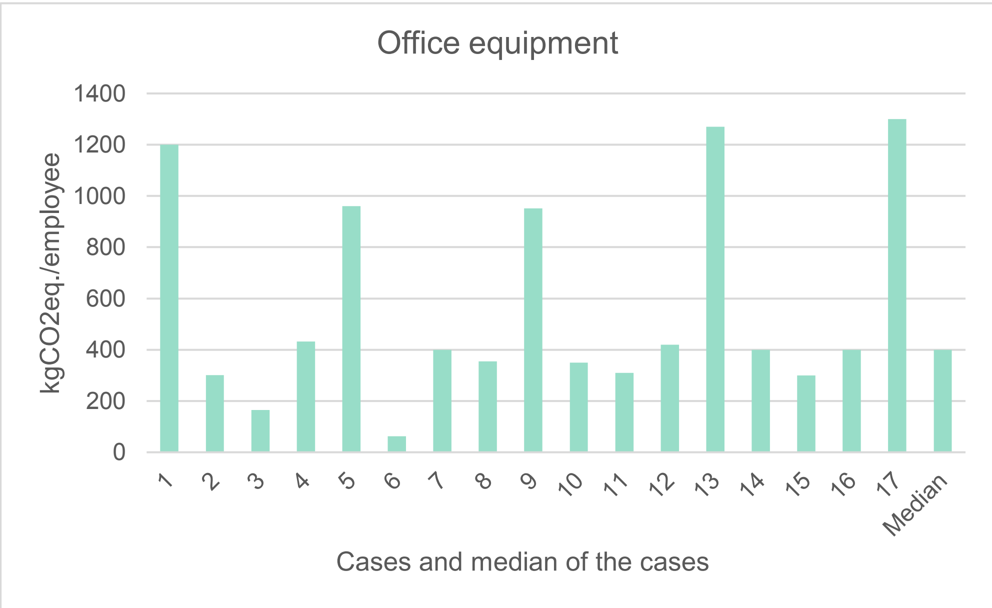


*Figure 9 Emissions caused by office equipment for cases 1-17. The median of all the cases is also presented in the figure.*

### *3.2.2.4 Purchased services*

The impact share from purchased services is demonstrated in Figure 10. The results vary a lot, from 3-48 %. The intangible services are not accounted for in cases 2-5, hence left out from the figure. Shrake et al. (2013), case 1, compares the finding of the importance of purchased services with Junnila (2006c), cases 10-13. In Junnila's cases the median impact of purchased services is 8 % while Shrake et al. find the impact to be 24 %. The explanation given by Shrake et al. (2013, p. 269) is that the studies use different I-O data (2002 vs. 1998 in Junnila's study) as well as different LCA guidelines. Any further reasoning is not given. Overall, the results show that purchased services can have a significant life cycle impact and should therefore not be neglected nor initially assumed to not have an environmental impact. The lowest absolute emissions are 120 kg$CO_2$eq./employee by case 10, which is higher than the median for office supplies, once more emphasizing the environmental impact by service oriented companies. The company represented by case 10, calculated as a hybrid-LCA, is also represented by case 14 determined by a more process based hybrid-LCA including additional supply chain stages compared to case 10 calculations. Case 14 is therefore showing greater emissions. The highest impact is shown by case 17 with a total of 10 200 kg$CO_2$eq./employee. The median for purchased services is 1000 kg$CO_2$eq./employee.

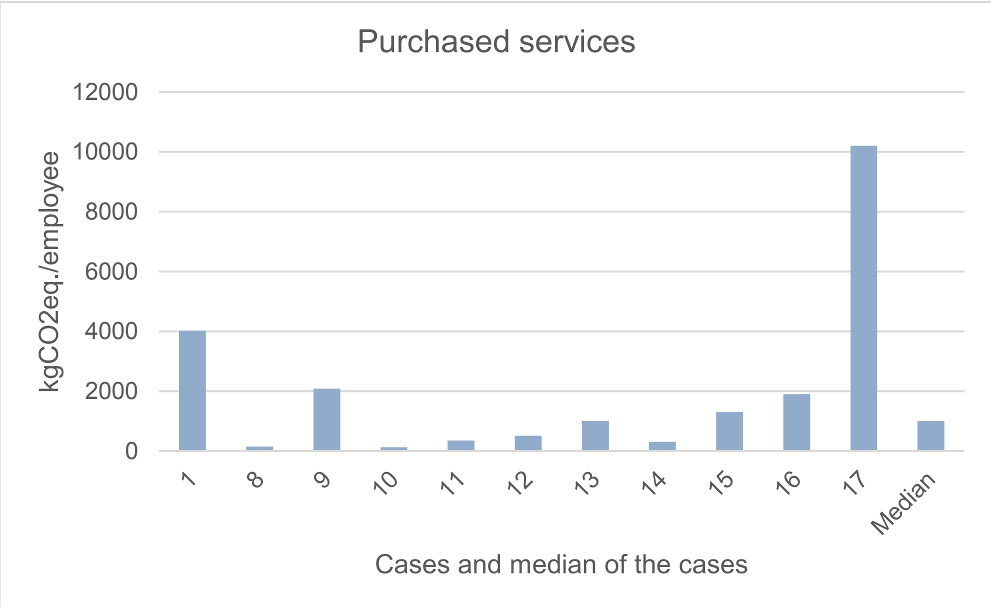


*Figure 10 Emissions caused by purchased services for cases 1 and 8-17. In the remaining cases, the impact from purchased services was left out. The median of the cases is also presented in the figure.*

Looking at Figure 5 it can be seen that even though the companies studied have substantially different characteristics (location, number of employees, ways of working etc.) and lines of business (all still being service oriented companies e.g. banking, consulting and management companies) the carbon footprint (expressed in kg$CO_2$ equivalents per employee) is very similarly distributed between the categories. The absolute emissions though vary a lot, from a total of approximately 3000 kg$CO_2$eq./employee up to 21 100 kg$CO_2$eq./employee. The median for the companies is approximately 5900 kg$CO_2$eq./employee in a year. This shows that the methods used, and the characteristics of the company has a great impact on the absolute emissions even though the distribution between them is similar for all cases. According to these studies, the distribution shows that most companies should focus on the same areas to decrease their environmental impact; building premises, business travel and commuting. However, the other categories, especially purchased services, cannot directly be assumed to have a low impact.

### 3.2.3 Empirical comparison of different LCA methods

Cases 8 and 9 studied by Junnila (2006b) demonstrate an empirical comparison of a PRO-LCA and an IO-LCA (also known as EIO-LCA). A similar division into tangible and intangible expenses, as in cases 2-6, was made for cases 8 and 9. However, from the intangible expenses, this time purchased services were assumed to have an environmental impact. From the results (Figure 5) it can be seen that the IO-LCA places emphasis on the purchased services (34 % vs. 5 %), while the office premises (electricity, heating and construction) have less weight compared to the PRO-LCA. In general, as seen in Figure 11, the IO-LCA gives higher results in most categories. The biggest difference is caused by the cut-off in purchased services for the PRO-LCA due to lack of supply chain information (especially in restaurant and catering services, which has the biggest impact of the purchased services in the IO-LCA). Other significant differences are in:

- construction, explained by the difference in building material manufacturing processes (PRO-LCA data is mainly from Finland while IO-data is from the U.S)
- office equipment, explained by lack of supply chain information in the PRO-LCA
- business travel, explained by the shares of long vs. short distance flights (long distance flights having a lower $CO_2$ intensity).

The conclusion made by Junnila (2006b) of the empirical comparison is that the approaches give different results because of both methodological and data quality reasons. However, both methods show the same division of significance between activities and processes, with purchased services as an exception. Therefore, based on this research, it seems that both methods (IO with U.S.-based data, PRO with process data) are applicable for a screening LCA with the purpose of determining the most environmentally significant activities and processes of service oriented companies in Europe.

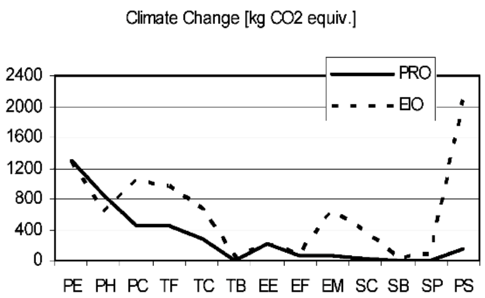


*Figure 11 Empirical comparison of PRO-LCA and IO-LCA (PE = premises, electricity; PH =premises, heat; PC = premises, construction; TF = travel, flights; TC = travel, cars; TB = travel, buses and other public transportation; EE = office equipment electricity; EF = office furniture; EM = office equipment manufacturing; SC = supplies, copy paper; SB = supplies, books and papers; SP=) supplies, pens etc.; PS = purchased services). (Junnila, 2006b, pp. 7072-7073.)*

| | climate change [kg $CO_2$ equiv.] | |
|---|---|---|
| | **PRO** | **EIO** |
| office premises | 2586 | 2922 |
| electricity | ***1288*** | *1268* |
| heating | ***847*** | 617 |
| construction | *451* | *1037* |
| business travel | 744 | 1678 |
| flights | *454* | *965* |
| passenger cars | 290 | 671 |
| buses, trains, etc. | 0 | 41 |
| office equipment | 355 | 951 |
| electricity | 210 | 207 |
| furniture | 73 | 92 |
| manufacturing | 72 | 652 |
| office supplies | 31 | 500 |
| copy paper, etc | 29 | 363 |
| books and papers | 1 | 44 |
| pens, staple, etc | 0 | 93 |
| purchased services | 145 | 2078 |
| restaurants | n/a | 762 |
| advertising, marketing | n/a | 210 |
| hotels | n/a | 188 |
| communication | n/a | 184 |
| O&M facilities | n/a | 127 |
| postal services | n/a | 102 |
| recreational services | n/a | 102 |
| other services | 145 | 403 |
| total | 3861 | 8128 |

Shrake et al. (2013) compares results from a hybrid-LCA with the results calculated only by using EIO-LCA (Figure 12). The hybrid-LCA had more compounds available due to the use of process life cycle inventories in addition to IO-data. The IO-LCA database used has 465 emission sectors to choose from that can contribute to the results of each impact category. The process data records can include hundreds to thousands of substances, leading to the hybrid-LCA having more substances contributing to the results. Further the aggregation of sectors affects the results of the IO-LCA. Shrake et al. (2013) concludes that IO-LCA alone cannot give detailed enough results for making specific improvements in a service oriented company. Still it can be an effective tool for performing a screening LCA aimed at finding the biggest impact categories that then can be looked into in more detail.

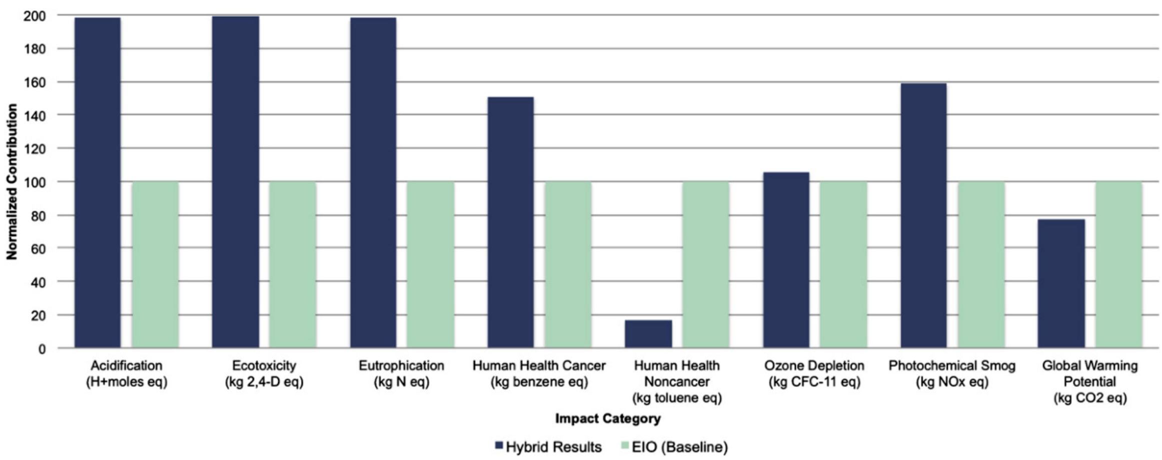


*Figure 12 Comparison of a hybrid-LCA (dark blue) and IO-LCA (light blue) for a service oriented company (Shrake et al. 2013, p.269).*

### 3.2.4 Environmental impact of energy

Building premises caused most of the emissions in almost all cases in the studies in chapter 3.2.Within building premises it was energy usage that stood for most of the emissions.

Energy is produced in different ways using different energy sources. Figure 13 compares the electricity generation in Finland (outer circle) and the U.S. (inner circle), which differ significantly. All energy sources have an environmental impact and emit GHGs. According to IPCC (2014) electricity and heat production stood for 24 % of the global GHG emissions in 2010, having the biggest share of the emissions. Whilst e.g. industry contributed to 21 % (second biggest share) and transport to 14 % of the global GHG emissions.

Weisser (2007) did a literature study on the life-cycle emissions from selected energy technologies for electricity production. The study shows that the most emitting technologies are lignite, coal and oil power plants while hydro, nuclear and wind are the least emitting technologies. Figure 14 shows a summary of the results from Weissers study. Weisser points out that the upstream emissions can be up to 25 % of the cumulative emissions for fossil fuels and that 90 % of the emissions from renewable energy technologies and nuclear can be upstream and downstream emissions. Therefore, it is important to study the life-cycle emissions from energy production, not only direct emissions. Further the issue of carbon leakage is mentioned. The generation and use of electricity in one country can release significant amount of GHGs in another country. For example, in the UK the use and import of natural gas increased as an action towards reaching the Kyoto Protocol obligations. It is imported e.g. from the Middle East where no constraints regarding GHG emissions exist.

The leakage issue may hence lessen the emission improvements made in the UK. This shows that in order to understand the actual emissions, indirect emissions need to be accounted for as well. (Weisser 2007.)

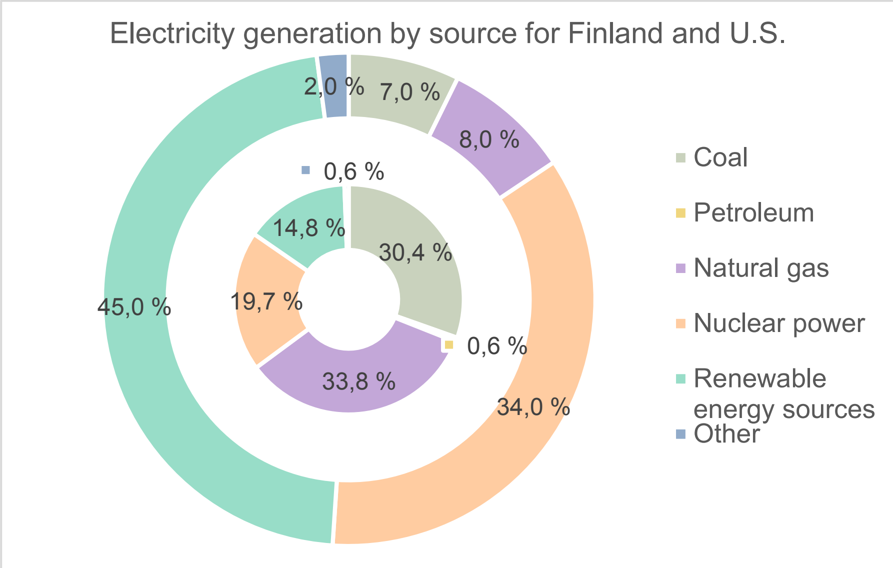


*Figure 13 Electricity generation by energy source for Finland (outer circle) and U.S. (inner circle) (EIA 2017; OSF 2016).*

The use of renewable energy and nuclear has environmental benefits and can decrease the emissions from electricity production. However, these energy sources may not have enough capacity at competitive prices to dominate the power supply in the short- to medium-term. To meet the growing energy needs and reduce the GHG intensity of the energy sector a combination of mitigation policies will be needed. Weisser list five options: (1) more efficient conversion of fossil fuels, (2) switching to low-carbon fossil fuel, (3) increasing the use of nuclear power and (4) renewable sources of energy and (5) decarbonisation of fuels and flue gases, and carbon capture and storage (CCS). All these options can help to reduce the GHG emission intensity of energy production.

The emissions from energy usage is highly dependent on the energy source and production. Only focusing on decreasing the emissions from energy production and believing in more energy efficient technologies is not enough though (Koivisto 2008, p. 125). Emphasis should also be put into decreasing the energy usage. It also has financial benefits in addition to environmental benefits.

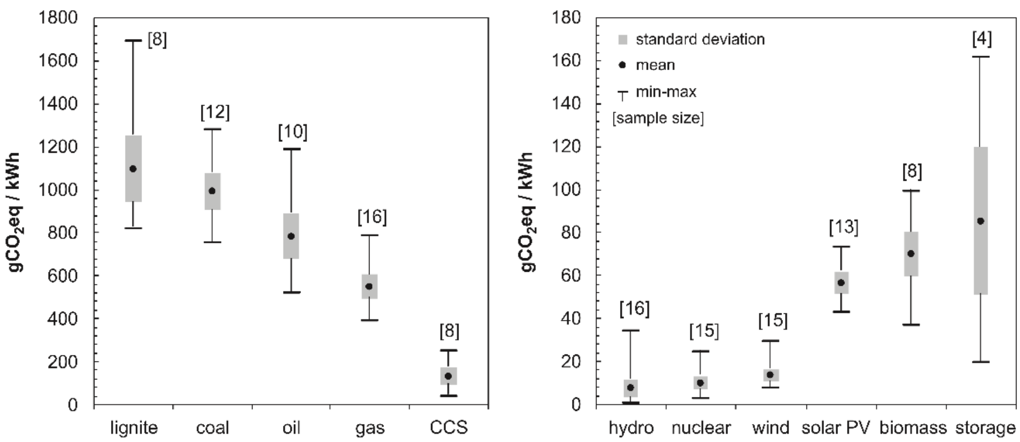


*Figure 14 Life-cycle GHG emissions from selected energy technologies (Weisser, 2007)*

### 3.2.5 Environmental impact of transportation

Business travel and commuting was one of the categories with the biggest emissions according to the studies presented and discussed in chapter 3.2. Travelling has a big impact on the environment and causes pollutions contributing to climate change. Transportation was one of the key sectors in the 1997 Kyoto Protocol where the aim was set to reduce the global GHG emissions by 5,2 % compared to the 1990 levels (Chapman 2007, p.355). It stands for approximately 19 % of the global energy use, 23 % of the global $CO_2$ emissions from fuel combustion and for 29 % of the OECD countries' $CO_2$ emissions. (Chapman 2007, p. 354; OECD/IEA 2016b, p.7, 2016a, p. 9, 2009, p. 29). In the OECD countries the division between transportation modes is: 81 % road, 13 % air, 2 % water, 2 % rail, 2 % pipeline (Chapman 2007, p. 355).

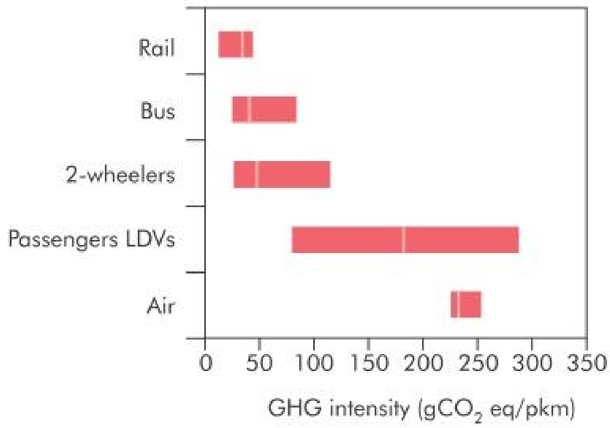


*Figure 15 GHG intensity of different passenger modes in 2005. The clear line shows the world average and the bars Mobility Model (MoMo) region's divergence. (OECD/IEA, 2009, p. 52.)*

Air travel is through its use of fossil fuels a significant GHG polluter and an important contributor to climate change. On a global level 3,5-4,6 % of the total anthropogenic (human) GHG emissions originates from international aviation and the share is expected to grow as the number of flights increases. (Becken 2007, p. 351.) Even though aviation is not the biggest polluter $CO_2$ emission wise it is more environmentally damaging than only indicted by the $CO_2$ emissions due to the other GHG it releases in the upper atmosphere (Chapman 2007, p. 356). Further, looking at emissions per travelled passenger kilometre in Figure 15, air travel is usually the least efficient option emitting most $CO_2$eq. per passenger kilometre. Regarding cars though, it depends on the distance. When considering very long distances air travel is more efficient than going by car. The efficiency values are however sensitive for vehicle type and load factors. In the U.S. for example, buses tend to carry less passengers and hence having higher $CO_2$ emissions per passenger kilometre. A more recent report from the European Environmental Agency (EEA) shows similar results (Figure 16), noticing that it only report carbon emissions not carbon equivalents.

Travelling by air and car are the most favoured passenger transport modes, which are also the most polluting alternatives. (Chapman 2007, pp. 356-357; OECD/IEA 2009, pp. 52-53.) The UK Department of Transport, DfT,) argues that either the preferred ways of transport need to become less polluting through new technologies or then alternatives have to become more appealing via policies and behavioural change (2005, in Chapman, 2007, p. 357). Even though new technologies have big emission reduction potential and significant emission reductions would not be possible without them, a solution relying only on technology would be difficult, expensive and slow and the increase in travel could cause a rebound effect.

Therefore, changes in behaviour and travel habits are more important and a key factor to enable the transport sector to do its share in relation to other sectors. (Becken 2007, p. 351; Chapman 2007, pp. 364-365.)

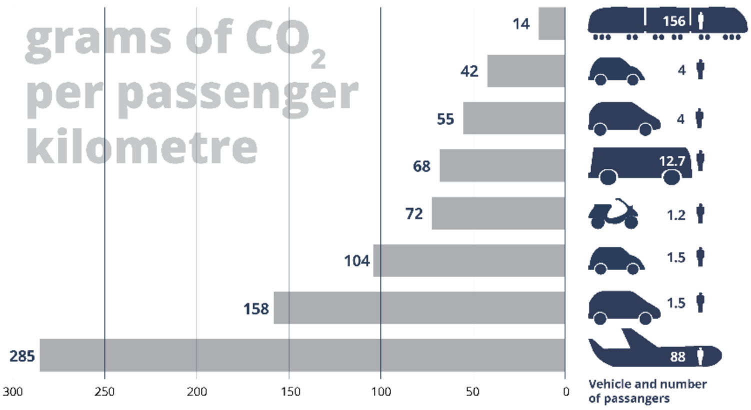


*Figure 16 $CO_2$ emissions from passenger transport (EEA 2014)*

### 3.2.6 Importance of waste management

Waste may not have a very big share of the emissions, but waste management is still important. Waste does not only cause emissions but has other negative impacts on the environment as well.

Recycling, a key component of modern waste disposal, is the third element of the waste reduction hierarchy "reduce, reuse, recycle" (Banerjee 2015, p. 53). The use of recyclable materials has, due to environmental, economic and technological developments, continuously increased worldwide (Asmatulu and Asmatulu 2011, p.131). Recycling is a series of activities. It consists of collecting any kind of recyclable material and devices (that otherwise is considered waste), sorting them and the process turning the waste into new raw materials and products.

Positive impacts related to recycling are: preventing potentially useful materials from becoming waste, conserving natural resources, reducing extraction and consumption of fresh raw materials and reducing energy usage, air pollution (GHG emissions), soil pollution and water pollution by decreasing the need for conventional landfills. Further it can increase economic value and create job opportunities. It was during the 1970's that significant investment in recycling happened because of rising energy costs. The saved energy is noticeably greatest for aluminium where recycled aluminium only uses 5 % of the energy needed for fresh production. The energy savings are less dramatic, yet significant, when using recycled paper, glass and metals. For example, the energy usage for paper manufacturing is reduced by over 60 % by recycling. (Asmatulu and Asmatulu 2011, pp. 131, 134-135; Banerjee 2015, p. 53.)

However, recycling is not positive throughout, there are naturally inevitably aspects as well. Cost, transportation, diffusion of hazardous materials in the recycled materials and limited application of recycled materials (no guarantee of the quality for direct use) are examples of the negative aspects. Further the recycling plants may become unhealthy and unhygienic for workers and nearby communities if the recycling process cannot be controlled properly. However, recycling has enormous potential and can have great environmental (less energy usage, contamination, pollution and emissions), economic (money savings through less raw material extraction and energy usage, jobs) and social (endorsing social interactions and community development, increased lifespan through e.g. cleaner environment and safer working conditions) impacts. It is believed that traditional design, analysis and manufacturing methods will change due to more research and development in recycling, resulting in variety of recycled products. (Asmatulu and Asmatulu 2011, pp. 133-135.)

The success of recycling is clearly dependent on the participation of individuals throwing the trash. It has been shown that knowledge about recycling and environmental issues in general have a great impact on recycling behaviour. (McCarty and Shrum 1994, pp. 53-54.) The findings of McCarty and Shrum (1994, p. 58) demonstrated that the feeling of inconvenience is strongly related to weather people recycle or not. Hence, making recycling as effortless as possible is more important than people believing in the importance of recycling, yet the attitude towards recycling and its importance should not either be neglected.

### 3.2.7 Scenario analysis and impact intensity

Junnila (2006a) researched different scenarios for a median organisation, constructed based on the service sector organisations studied, in order to test the impacts of changes in the company. 32 scenarios were tested and out of them 20 had only modest impact but some had a considerable impact. The scenarios related to energy consumption in the building and electricity production mix had the biggest influence (> 20 %) in both directions (positive and negative). In addition, optimistic commuting vehicle mix, optimistic average length of daily commuting, optimistic and pessimistic space usage efficiency and refurbishment period scenarios affected the results around 10 % compared to the median organisation.

Money is often something that interests companies and therefore Junnila (2009) compared the economic cost and environmental impact of service oriented companies in one operational year. Wages, social expenses and daily allowances for the employees accounted for 45-80 % of the budgets while these are assumed to not cause any environmental impact. The office premises, on their part, stand for less than 10 % of the costs but cause around 50 % of the environmental impacts. Money spent on purchased services ranged from 10-35 % and the environmental impact from 8-50 %. The climate change intensity (impact per cost of activity) was highest for office premises (400-1200 kg $CO_2$eq./€), followed by business travel (350-900 kg $CO_2$eq./€). The intensity of office equipment, supplies and purchased services was 100-300 kg $CO_2$eq./€ for all three categories.

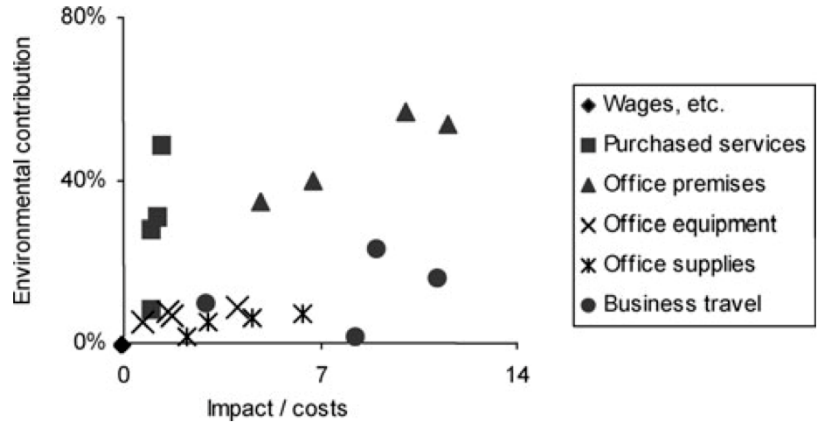


*Figure 17 The environmental contribution (proportion of the aggregated normalised impacts) and the impact intensity (aggregated normalised impacts per costs) of the main processes in four service oriented companies. (Junnila, 2009, p. 431)*

Figure 17 shows that companies have the greatest potential for absolute environmental impact reduction and also the best efficiency by cutting the costs in the premises. The intensity of the business travel varies between the companies, meaning that some companies can reduce overall environmental impacts efficiently by cutting costs in the category while it for others would have a low influence. The purchased services show a high environmental contribution but low intensity. This implies that companies bought different amounts of services and that the environmental impact of services essentially depends on the amount of purchased services and not their type. The intensity of office equipment and supplies is relatively low, suggesting that downsizing these activities will not decrease the environmental impact as much as downsizing within the offices premises of business travel categories.

### 3.2.8 Examples of possible improvements

In the case study by Shrake et al. (2013) they also suggested some improvements that could be made by the company to decrease its environmental impact. The hybrid-LCA had revealed that the most effective categories for decreasing the environmental impact where the building premises, commuting and business travel. In order to reduce commuting the following was suggested: flexible scheduling to avoid rush-hours or telecommuting to reduce physical commuting e.g. from five to four days a week. To decrease the impact of business travel without changing the business practices it was suggested to shift to more efficient vehicles. In the office premises lightning and office equipment were found to use most energy. The reality was that the lamps and ballasts had not been changed since the premises were constructed in 1990 and that the employees did not use any power saving settings in their computers (screen brightness, sleep mode after inactivity). The initiative for power saving resulted in an around 20 % decrease in off-hour energy consumption. The implementation project had a payback of less than one year. Moreover, implementing a new waste reduction and recycling program was suggested. The goal was to minimize unnecessary paper waste and guarantee correct recycling.

### 3.2.9 Conclusion of comparison

Seen from this comparison the biggest impacts are generally generated from the office premises, commuting and transportation. The results are, however, dependent on the LCA method used and the availability of data and characteristics of the company studied. The normalized proportions of the impact categories are, however, very similar despite the differences between the assessments. For a screening LCA with the aim to find the biggest emissions contributors all methods showed to be applicable.

# 4 Determining the environmental impact

The environmental impact can be determined in many different ways using different tools, models and guidelines. Life-cycle assessment is one commonly used tool and it is often seen as the most appropriate tool to be use. An application of the LCA framework is the carbon footprint which has become a commonly accepted method to address the environmental impact.

## 4.1 Life cycle assessment

A life-cycle assessment (LCA) is a “cradle to grave” analysis, where the basic idea is to consider all environmental burdens related to a product or service, all the way from the raw materials until it becomes waste (Klöpffer 1997).

As the society becomes more concerned about environmental issues, business responds to the customers demand by providing more environmentally friendly products. One of the tools to help improving the environmental performance is LCA. LCA provides a comprehensive and more accurate view, than traditional analysis, of the true environmental impact. It includes impacts from all stages of a product’s or service’s life cycle, often considering impacts that are not included in more traditional analyses. (SAIC 2006, p.1.) For a holistic environmental assessment, the LCA framework is often recognised as the most suitable method, according to Junnila (2006a).

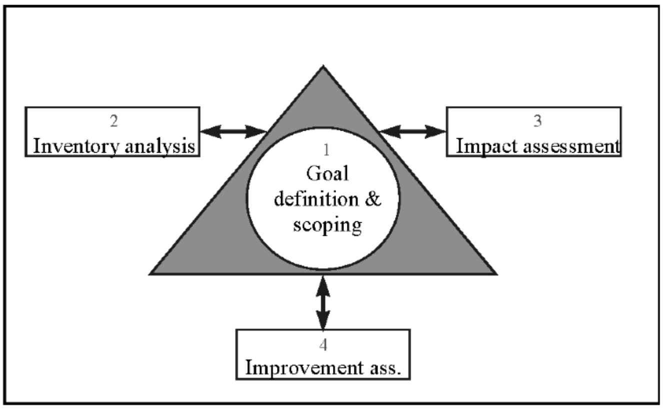


*Figure 18 The SETAC-triangle (Koroneos C.J. and Koroneos Y. 2007, p.427)*

Environmental life-cycle assessment dates back to the 1960’s when the concern about finite natural resources rose. The interest to predict future resource supplies increased. The oil shortage in the early 1970’s further raised the interest about product’s environmental effect. However, after 1975, when the oil crisis was over, the interest shifted towards issues related to the management of hazardous waste. Life-cycle analyses were though still conducted in a small scale during this time. Then in 1988, when the issue of solid waste became worldwide, the life-cycle inventory analysis was once again used as a tool for evaluating environmental problems. (Curran 1993.) Between 1990 and 1993 the Society of Environmental Toxicology and Chemistry (SETAC) and SETAC-Europe organized several workshops to develop the LCA methodologies. This resulted in LCA-guidelines, “A Code of practice”, published in 1993. The basic structure can be described through the SETAC-triangle (Figure 18). This is also the base for the ISO standards, published by the International Standards Organization, about LCA methodology. In the ISO-LCA methodology the “Improvement Assessment” stage has been substituted by “Interpretation” to include more than one tool to evaluate the whole LCA (Figure 19). (Klöpffer 1997; Koroneos C.J. and Koroneos Y. 2007.)

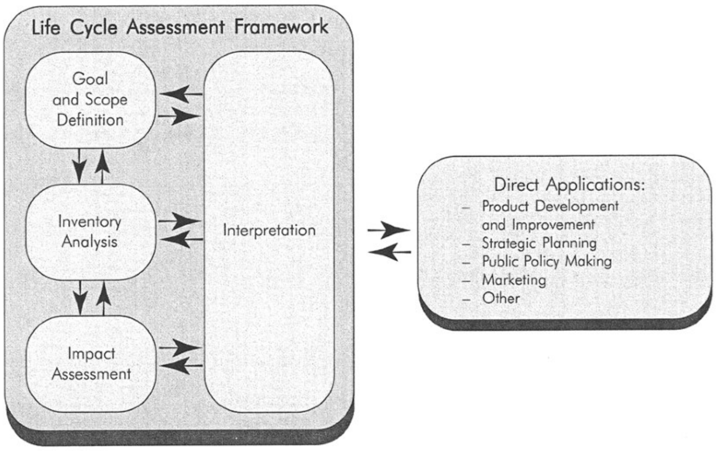


*Figure 19 The ISO-LCA methodology (Klöpffer 1997, p. 225)*

The goal and scope definition define why the LCA is performed, its goals, boundaries and elements, the system(s) to be analysed and more detailed aspects. The inventory analysis is the central, most scientific part of the LCA. All actions that are related to the production of a unit must be quantified and analysed, resulting in an inventory table, listing all inputs and output per functional unit. The two first parts can be called a stand-alone Life Cycle Inventory (LCI). An LCI can give valuable information about "product improvements, benchmarking, energy savings, and emission reduction". It is though not enough for the comparison of product systems. For this and to get a deeper understanding of the system(s) an impact assessment (LCIA) must be completed. (Klöpffer 1997.) The impact assessment

*Table 7 Impact assessment further divided into five steps (Koroneos, C.J. and Koroneos, Y. 2007; AquAeTer 2011)*

| Step | Explanation |
|---|---|
| **Selection and definition of impact categories** | Allows categorisation and characterisation of the data for the next step, interpretation. |
| **Categorisation / Classification** | Assigning the LCI results to the impact categories |
| **Characterisation** | Quantifying and accumulating LCI impacts in every impact category, using science-based conversion factors. E.g. GHG emissions to $CO_2$-equivalents. |
| **Normalisation / Grouping / Weighting** | Relating all potential impacts of a functional unit are to a reference situation, making it possible to compare alternative products. E.g. a ratio of GWP per functional unit / total GWP. / Sorting and ranking the indicators / Emphasising the most important potential impacts |
| **Evaluation and reporting** | Comparing results of characterisation and normalisation quantitatively and/or qualitatively to make the results of the different impact categories easier to read and use for decisions. |

can further be dived into five steps presented in Table 7. The interpretation phase aims to critically evaluate the whole LCA. The objective is to study the results, reach conclusions, clarify any limitations and based on the findings of the LCI and LCIA give recommendations. (Koroneos, C.J. and Koroneos, Y. 2007; AquAeTer 2011)

SAIC (2006, pp.5-6) reminds that converting data and impact results to one comparable score cannot be done based exclusively on natural science. There are many ways to perform an LCIA and the result of an LCA won't therefore be able to tell which product, service or process works the best or is the most cost effective. The results of an LCA can, however, be very helpful and useful in a more comprehensive decision-making process.

Finnveden et al. (2009, pp.14-15) emphasizes the importance of acknowledging the uncertainties and limitations related to an LCA. They divide uncertainties into sources (inputs) and types of uncertainties (different aspects of the inputs). The identify three different uncertainty sources: data (e.g. $CO_2$ emissions from a power plant), choices (e.g. system boundaries) and relations (e.g. linear dependence between the distance travelled and the fuel input). Types of uncertainties related to the earlier examples could be:

- Inaccurate data (e.g. typo, wrong unit, decimal error)
- Incomplete data (e.g. lack emission data from some burners in the power plant)
- Wrong specified data (e.g. specific data of the wrong burner model)
- Variability in data (e.g. the performance of similar burners may differ as well as the performance of a specific burner over time depending)
- Rounded data (e.g. using 0,3 instead of 0,354)
- Inconsistent choices (e.g. using different methods of allocation for different product chains)
- Wrong or incomplete relations (e.g. a linear dependency may not reflect the actual relationship)
- Inaccurate software implementation of relations (e.g. inversions may be sensitive to the choice of algorithm).

These are just some examples of uncertainties that may occur and when performing an LCA many types will occur. The article gives examples of how to deal with uncertainties and divide it into "scientific", "social" and "statistical" ways. The scientific way would be to do more research, the social way to discuss uncertainties with stakeholders and agree on data and choices and the statistical way would be to incorporate the uncertainty instead of getting rid of it, e.g. by making alternative calculations with different data values or by using classic statistical theory. Other limitations that Finnveden et al. (2009, pp.15-16) identify are:

- The data intensity and possible lack of data.
- The fact that not all impacts are equally covered in a typical LCA.
- The inclusion of many methodological choices that can cause uncertainty and may influence the results.

There are various guidelines and standards developed to support carrying out LCAs. They are trying to help creating a more standardised and reliable way of performing the assessments. Several guidelines and standards are presented in chapter 4.4.

## 4.2 Carbon footprint

Over the past years, the carbon footprint has developed into one of the most important indicators for environmental protection (Čuček et al., 2012, p. 10). Measuring the carbon footprint is a way to estimate the contribution one has to climate change (Matthews et al. 2008) and climate change is possibly the most recognised environmental impact of all (Whittaker et al. 2003 in Junnila 2009, p. 429).

The definition of the term “carbon footprint” is not as explicit as expected thinking of the growth in its use since the 1990’s, which is a result of the increasing awareness of climate change and environmental issues. (Matthews et al. 2008; East 2008). Carbon footprint has its roots in the term “ecological footprint” referring to the total land and sea area, expressed as global hectares, needed to produce a certain level of human consumption for a given human population. Continuing on this concept carbon footprint would mean the area needed to absorb the total amount of $CO_2$ produced by mankind during its lifetime. (Pandey et al. 2011; Matthews et al. 2008).

Despite the lack of a globally agreed definition of a carbon footprint the difference between ecological and carbon footprint is, however, apparent. The broader concept, the ecological footprint, considers a wider range of human actions with an ecological impact. Further it demonstrates the regenerative capacity of the environment through the equivalent area of productive land. The carbon footprint is a narrower concept, in general focusing on practices and processes emitting $CO_2$. In most definitions, it is explained as the physical quantity of $CO_2$ and other GHGs from a determined activity over its full life cycle. (East 2008; Čuček et al. 2012, p. 10)

According to Finkbeiner (2009) the carbon footprint concept has been around for several decades but just known with another name, global warming potential (GWP). A term used for a life cycle impact category indicator and its result. The carbon footprint has though evolved into an own concept and may be seen as a hybrid of these two concepts. Originating the name from the ecological footprint but the concept from the GWP indicator. (East, 2008; Pandey et al. 2011). Pandey et al. (2011) lists other terms associated terms for carbon footprint that sometimes may be used as synonyms: embodied carbon, carbon content, embedded carbon, carbon flows, virtual carbon, GHG footprint and climate footprint.

The term carbon footprint is widespread and popular in the public debate as an indicator for the contribution of an entity to the global warming and climate change. However, it is creating confusion over what it exactly means. (Wiedmann and Minx 2007; Hammond 2007; Pandey 2011; East 2008.) Carbon footprint may not be the most descriptive term if it is used as a synonym for greenhouse gases measured as $CO_2$ equivalents or as a generic term for emissions of carbon dioxide (Wiedmann and Minx 2007.) The concept carbon footprint often refers to tons or kilograms of $CO_2$ while a footprint is a spatial indicator (measured in hectares or square meters), therefore a more descriptive and less confusing term would be “carbon weight” (Hammond 2007). Wiedmann and Minx (2007) do not propose a new term but a clear definition of what carbon footprint is, as follows: "The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product." They find it relevant to only measure important $CO_2$ emissions when talking about a carbon footprint and if other GHG are included it should be called climate footprint instead. Further they argue that it is important to include both indirect and direct $CO_2$ emissions and that mass units (kg, t, etc.) should be used to avoid unnecessary conversions.

Even though the term carbon footprint is widely used there is not yet a consensus of the definition and the suitability of the term to describe the measure of GHG emissions is questionable. Another issue is the lacking control of carbon calculations performed by different instances. However, as legal and business requirements increase most calculations worldwide are following the GHG protocol (described further in chapter 4.4), creating some consensus. (East 2008; Pandey et al. 2011). Yet, despite the controversies regarding the carbon footprint Pandey et al. (2011) concludes that it can and even should still be used as a tool for promoting reductions of $CO_2$ and other GHG emissions and that it should also be included as an indicator for sustainable development.

Sinden (2009) lists some of the potential uses of carbon footprint information identified by the PAS 2050 guidelines (see chapter 4.4.2):

- Supporting internal valuation of existing life cycle GHG emissions of goods and services.
- Promoting evaluation of alternative products and services (sourcing and manufacturing methods, raw material choice, supplier selection) based on associated life cycle GHG emissions.
- Giving a benchmark for ongoing programs aimed at reducing GHG emissions
- Enabling comparison of goods or services using a common, recognised and standardised approach for LCA of GHG emissions
- Supporting corporate responsibility reporting
- Providing a common ground for reporting and communicating the results of GHG emission LCA, hence supporting comparison and consistency in understanding
- Helping consumers understand the life cycle GHG emissions allowing them to use the information when doing purchasing decisions and using products and services.

## 4.3 Calculation methods

The term carbon footprint is widely used by the media and the public in general. It has become a synonym for the impact individuals, communities, countries, companies and products have on climate change. However, as mentioned in the previous chapter (4.2), the academic world has not kept up with the spreading use of the expression carbon footprint and has not yet come up with one definition. Consequently, it is debatable which methodology to use for a carbon footprint analysis. Naturally a unit indicator for the carbon footprint should cover all emission that can be associated with an activity, both directly and indirectly. Traditionally this full lifecycle perception has, methodologically, been addressed in two ways, using the: the bottom-up process lifecycle analysis and the top-down input-output lifecycle analysis. (Wiedmann, 2009, pp. 176-177.) Different LCA methods are presented in more detail in the next chapters.

### 4.3.1 Process LCA

One of the basic methods to perform an LCA is the process analysis (PRO-LCA) (Suh et al. 2004, p. 658; Junnila 2006b, p. 7070). It has been developed to understand individual product's environmental impact from "cradle to grave" (Wiedmann, 2009, p. 177). The resource use and environmental releases of the main production processes are the main characters included in the analysis. In general capital goods are left out of the analysis, which can lead to substantial underestimations, especially in the LCI conducted for service companies where capital inputs can play a significant role.

The decision of which processes to include or not are often subjective choices, not scientifically motivated. Even though a subjective system boundary selection is allowed by the ISO standards, this can cause lack of confidence in the LCAs. The ISO standards still give general guidelines for how to draw an initial system boundary, but for a process based analysis it is difficult to meet these requirements. (Suh et al. 2004). According to the ISO 14040:2006 standard all inputs and outputs at the system boundary should be elementary flows, meaning all material and energy entering (leaving) the system drawn from (disposed into) the environment without any previous (subsequent) human transformation. It basically means that all processes that are directly and indirectly linked to the analysed system should be included. It would require closed clusters of processes, which is seldom the situation in an increasingly interdependent global economy where all processes can be said to be directly or indirectly connected. (Strømman and Solli 2008; Suh et al. 2004; Mongelli et al. 2005).

The process analysis is often seen as detailed but cost and labour-intensive method that is suffering from abbreviation, also called the truncation error. The high level of detail originates in the detailed emissions estimation based on energy and mass flows within a process. The abbreviation error is a consequence of the finite boundary of the analysed system leaving out contributors outside of the boundary. (Suh et al. 2004; Wiedmann 2009). Excluding processes naturally leads to an underestimation of the environmental impact, which could be up to 50 % (Mongelli et al. 2005, p.317).

### 4.3.2 Input-Output LCA

Wassily Leontief developed input-output economics already in the 1930's after which it became an important branch in the science of economics. During his lifetime Leontief then applied input-output approach to many different topics, among them the choice of technology, trade in the world economy and environmental pollution. (Davar 2000). The LCA input-output method (IO-LCA) offers an alternative method to the process analysis and is an environmentally extended analysis that makes system cut-offs unnecessary (Wiedmann 2009, p.177). It is often referred to as the EIO-LCA (economic input-output LCA), because it uses money transactions as a base for the LCI. This is an advantage as such data is collected on a regular basis. Further the IO-LCA analysis can consider capital goods and overhead costs (e.g. company cars, marketing etc.), which process analyses often leave out on purpose. Studies have shown that excluded processes can have an as big impact as the included ones. (Suh et al. 2004). It is suitable for larger entities, such as product groups, companies or nations and once a suitable IO model has been set up several analyses can be performed in a resource efficient way (Wiedmann 2009, p. 177).

If the process analysis is seen as labour-intensive with abbreviation errors, IO-LCA has it owns weaknesses. Its appropriateness to measure the impacts of individual products is limited as it combines several products and production technologies to sectors, even though they would differ regarding prices, material inputs, outputs and environmental impacts. Hence, due to the assumed homogeneity at sector level, it cannot be seen as a detailed LCA. (Suh et al. 2004; Wiedmann 2009; Mattila et al. 2010.) For example, it does not make a difference between different types and models of computers, it only gives a general value (Carnegie Mellon University Green Design Institute 2008b.). Neither does it distinguish between a 50-year old coal plant and a modern combined-cycle gas turbine when generating electricity (Hendrickson et al. 2006, p. 16). Additionally, even if the production technology would be the same, there can be significant institutional differences. Differences in prices (typically used as the unit to represent transaction in IO tables) between industries can also cause uncertainties, as well as the assumption that imported and domestic goods are produced in the same way, using the same technology and resources. Further fast developing sectors may cause errors as the IO tables usually are several years old as well as incomplete environmental statistics and emission inventories. (Suh et al. 2004). Therefore, an IO-LCA is best suitable for analysing only a part, not a whole system in detail. (Treloar et al. 2000.)

There are advantages and disadvantages to both methods. Generally, PRO-LCA models are more precise but more time consuming because of the difficulty related to getting detailed inventory data. The IO models are, in contrary, more efficient and avoiding the cut off error, though introducing significant aggregation errors and price uncertainties. (Huang et al. 2009, p. 8510.) Hendrickson et al. (2006) have listed the strengths and weaknesses of both methods in more detail, presented in Table 8 together with some limitations indicated by Junnila (2006b):

*Table 8 Comparison of Process LCA and IO-LCA (Hendrickson et al. 2006, p. 27; Junnila 2006b, p. 7074).*

| | Process LCA | IO-LCA |
|---|---|---|
| **Advantages** | • Detailed and process-specific<br>• Specific product comparison<br>• Identifying weak points and process improvements<br>• Product development assessment | • Economy-wide and comprehensive<br>• System LCA (industries, goods and services, national economy)<br>• Sensitivity analyses and scenarios<br>• Publicly available data and reproducible results<br>• Product development assessment<br>• Information for all goods and services in the economy |
| **Disadvantages** | • Subjective system boundary setting and unavoidable cut-offs<br>• Generally time intensive and costly<br>• New process design difficult<br>• Use of proprietary data<br>• Cannot be replicated if using confidential data<br>• Data uncertainty | • Some product assessments contain aggregated data for a sector instead of detailed data for a process<br>• Process assessment difficult (due to the use of aggregated data) e.g. institutional variations (share of long and short distance flights), industry-atypical products (manufacturing of construction material)<br>• Price inhomogeneity. Difficulty in linking monetary values to physical units<br>• Past practises may be reflected in economic and environmental data (rapid development e.g. electricity production)<br>• Imported products treated as U.S products<br>• Difficult to apply to an open economy (with substantial non-comparable imports)<br>• Problem with availability of non-U.S data and outdated data.<br>• Data uncertainty |

### 4.3.3 Hybrid-LCA

To get the best of both worlds a method called the hybrid-LCA has been developed, where the strengths of the process and the input-output method have been combined to give more accurate results. In a traditional process LCA many processes are excluded while the input-output method suffers from built-in errors when applied on specific products. Therefore, the hybrid method is arguably the best option for a detailed, comprehensive and robust carbon footprint analysis. It allows the use of the detailed and accurate PRO-LCA for the assessment of important processes while most of the less significant factors can be accounted for by the input-output part of the model. (Treloar et al. 2000; Hendrickson et al. 2006, pp. 26-27; Wiedmann 2009, p. 177.) The term hybrid means two things in this context: first it refers to the combination of monetary and physical units, second it means the integration of the process and input-output data (Suh et al. 2004; Lee and Ma 2013). Several authors recommend to first perform a quick IO-LCA, then extract the most important pollutant pathways and use PRO-LCA for them (Mattila et al. 2010). Four basic steps of a hybrid model have been defined (Treloar et al. 2000; Lee and Ma 2013):

1. Determine an IO-LCA model
2. Identify and pull out the most important pathways for the sector under evaluation
3. Derive specific data for the product and its components
4. Insert and substitute the more detailed data into the IO-model.

The combination of process and IO-data has its roots in the 1970's when it started to be practised in the field of energy to make a hybrid energy analysis. A broader use of hybrid-LCA has not been spreading fast and since the 1990's many separate, individual suggestions have been made. The different types can be divided into three main categories of hybrid analyses (Suh et al. 2004; Bilec et al. 2006):

- Tiered hybrid analysis – direct and downstream plus some essential lower order upstream requirements are studied by the detailed process analysis while the remaining high order requirements are measured by the IO-analysis. The boundary between process and IO-analysis depends in general on data availability, detail and accuracy requirements and constraints regarding costs, labour and time.
- Input-Output-based hybrid analysis – important IO-sectors are further divided into smaller parts, if more thorough sectoral economic data is available, and then assessed with the process analysis.
- Integrated hybrid analysis – the process analysis is performed using a technology matrix where the data is presented as physical units per unit operation time of each process and the IO-systems are presented in monetary units. In this model, detailed information in physical units is entirely merged into the IO-model.

The hybrid method is used to achieve more accurate results by covering the cut offs (truncation error) in the detailed PRO-LCA by the completeness of IO-data. It uses the strength of both methods to receive a more detailed and comprehensive analysis. (Mongelli et al. 2005; Mattila et al. 2010.)

## 4.4 Standards and guidelines for GHG accounting

There are several guidelines and standards developed to help perform an LCA and guide in GHG accounting. The existence of many guidelines is one reason to the diversity among assessments of GHG emissions. The GHG protocol is one of the guidelines, which is widely used and accepted worldwide for guiding GHG accounting.

### 4.4.1 The GHG Protocol

The mission of the Greenhouse Gas Protocol (GHG Protocol) was launched in 1998: to develop internationally accepted tools and standards for GHG accounting and reporting, and to promote their implementation and use in order to achieve a worldwide low emission economy. The GHG protocol is a multi-stakeholder partnership consisting of governments, businesses, NGOs and others brought together by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). Several separate but complementary standards, guidelines, and protocols have been produced and published by the GHG Protocol. Among them the “GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard” (also called the “Scope 3 Standard”) which should be used in combination with the GHG Protocol Corporate Accounting and Reporting Standard, Revised Edition (2004), to which it can be seen as a supplement. The latter protocol has spread internationally and been used by business, governments and NGOs worldwide as the international standard for developing and reporting GHG inventories. It is complemented by the Scope 3 Standard, which builds on the Corporate Standard. The Scope 3 Standard endorses companies to include indirect emissions from value chain activates and promotes additional constancy and comprehensiveness in the accounting and reporting of indirect emissions. (WRI and WBCSD 2011, pp.3-5.)

Most protocols, including the Corporate Standard, divides a company’s GHG emissions into direct and indirect (both upstream and downstream) emissions, further categorized into three scopes (Figure 20) (WRI and WBCSD 2011, p. 5; Lee and Ma 2013, p.18; Matthews et al. 2008, p.5839; Wiedmann 2009, p. 178):

- Scope 1 – Direct emissions from owned or controlled sources, e.g. from company vehicles
- Scope 2 – Indirect emissions from the generation of purchased and consumed energy by the reporting company
- Scope 3 – All other indirect emissions generated in a company’s value chain, e.g. employee commuting

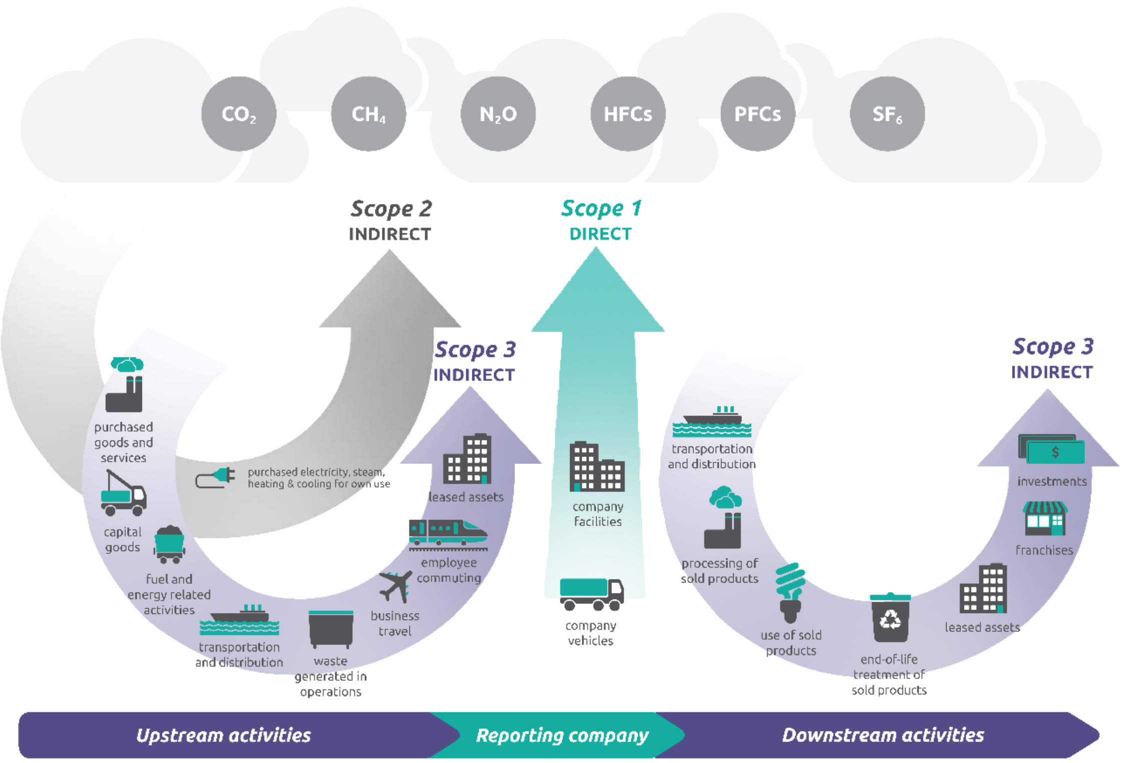


*Figure 20 An overview of the three GHG protocol scopes and the emissions across the value chain (GHG Protocol 2011, p. 5)*

The Corporate Standard requires that companies take into account and report all scope 1 and 2 emissions but is flexible regarding the accounting of the scope 3 emissions. However, since 2004, when the Corporate Standard was last revised, the expertise in GHG accounting has grown and through that the realization of the significance of emissions resulting from value chain activities (scope 3). (WRI and WBCSD 2011, pp.4-6.) For an industry sector, on average more than 75 % of the sector's carbon footprint is related to scope 3 emissions (Matthews et al. 2008, p.5839; Huang et al. 2009, p.8509). The capability of and need for businesses to count GHG emissions has grown significantly and corporate leaders have become more experienced and skilled in reporting the scope 1 and 2 emissions. Still, the indirect scope 3 emissions may represent most of a company's emissions and hence be the most significant part to report. The Scope 3 Standard is meant for all sized companies within all economic sectors and it can be used by other, both public and private, kinds of institutions and organisations, e.g. NGOs, universities and government agencies. (WRI and WBCSD 2011, pp.5-6.)

The reporting period is usually one year. Reporting in conformance with the Corporate Standard and the Scope 3 Standard requires calculating the emission for the six main GHGs (carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride ($SF_6$)) generated from the corporate value chain activities. The Scope 3 Standard does not consider avoided emissions or emissions reductions gained through emission compensation or offsetting. These kinds of reductions are addressed in another GHG protocol, the GHG Protocol for Project Accounting. Nor is the standard intended for comparison between companies, but for comparison within a company and its GHG emissions over time. It helps companies to identify the biggest GHG reduction opportunities across the corporate value chain, to track performance and to manage emission related risks and opportunities in an effective way. Further, as companies often have the possibility to influence their suppliers, through a broader inventory, companies may stimulate more effective corporate climate change policies. A comparison between companies is difficult because e.g. inventory methods, company size and structure may cause differences in the reported emissions. It would require further measures e.g. consistency in the data used for the calculations and in the methodology in general as well as additional information for example regarding intensity rations or metrics. GHG Protocol can provide additional consistency through GHG reporting programs or sector-specific guidelines. (WRI and WBCSD 2011, pp.7-11.)

The GHG Protocol tools and guidelines are accepted worldwide and is also used as a base for other GHG accounting guidelines including the ISO 14064. Further the GHG protocol is widely used as guideline when performing carbon footprint calculations, which have become a strong way of expressing the emission of GHGs. (Pandey et al. 2011, pp. 143-156.)

### 4.4.2 Other standards and guidelines

Other common resources for standard and guidance for GHG accounting are PAS 2050, 2006 IPCC, ISO 14064, ISO 14025 and ISO 14067. (Pandey et al. 2011, p. 143). According to Gasiorowski-Denis (2006) the most recognised standards for guiding LCAs are the two ISO standards ISO 14040:2006 – Principles and framework and ISO 14044:2006 – Requirements and guidelines, published by the International Standards Organization.

#### *4.4.2.1 PAS 2050*

PAS 2050, Publicly Available Specifications-2050, was first published in 2008 by the British Standard Institution (BSI) and revised in 2011. It specifies requirements for performing an

LCA for GHG emissions of goods and services. (BSI 2011; Pandey et al. 2011) The PAS 2050 was developed to be an internationally applicable and globally common method, avoiding country-specific approaches (Sinden 2009, p.202). It emphasizes the fact that GHG emissions arise from supply chains between businesses, within business and between nations. GHG emissions calculated for goods and services reflect all emissions throughout their life cycle and hence the impact of processes, materials and decisions connected to them. The PAS 2050 is only focusing on one environmental issue related to goods and services, the GHG emissions and their role in climate change. It requires that both emissions to and removals from the atmosphere are taken into account in a product's total GHG emissions over its lifecycle. The PAS 2050 specification includes requirements that limits the LCA approach to carbon footprinting. However, there are several possible environmental impacts which relative importance may vary considerably from product to product. Hence PAS 2050 recognises its limits and underlines the importance to recognise that decisions regarding a good or service made based on an assessment of a single environmental issue, could be harmful to other potentially arising environmental impacts from the supplying and use of the same product. (BSI 2011; Sinden 2009, p.195.)

The PAS builds on initial work by the Carbon Trust about carbon emissions in the supply chain and on the ISO standards 14040 and 14044. Further PAS 2050 also combine the most relevant principles of these documents with additional GHG assessment methods and approaches among which are ISO 14064, IPCC publications and the GHG Protocol. (Sinden 2009, p. 197.)

#### *4.4.2.2 2006 IPCC*

The 2006 IPCC guidelines for National Greenhouse Gas Inventories were first published in 1996. All countries that have signed the UNFCCC, and are committed to inform their national inventories of GHG emissions and removals, follow these guidelines. This makes the GHG inventories comparable between countries. (Pandey 2011, p. 143.) The guidelines have been structured in such a way that any country should be able to provide reliable estimates of their GHG emissions and removals, despite of level of experience and access to resources. They provide default values for the required parameters and emissions in all sectors, which means that, in principle, countries do not need to supply more than national activity data in order to report their GHG emissions and reductions. Nevertheless, it allows countries to use more detailed and single-country approaches as long as the compatibility, comparability and consistency between countries remains. Guidance to identify areas of improvement that would benefit the inventory the most is also provided. Thanks to this, limited resources can be concentrated on the areas which most need to be improved in order to advance the inventory towards its best. Additionally, the IPCC maintain and regularly update the IPCC Emissions Factor Database (EFDB). It was launched in 2002 and functions as a resource for inventory authors. It provides an archive of emission factors and other relevant parameters that can be of use for more detailed and country-specific methods. (IPCC 2006.)

#### *4.4.2.3 ISO standards*

There are several environmental management ISO standards dealing with life cycle assessment. According to Gasiorowski-Denis (2006) the most recognised standards for guiding LCAs are the two ISO standards ISO 14040:2006 and ISO 14044:2006. Pandey (2011) listed the standards ISO 14025, ISO 14064 (part 1 and 2) and ISO 14067 to be common resources for GHG counting.

The ISO 14025 (Environmental labels and declarations—Type III environmental declarations—Principles and procedures) is a standard for carrying out an LCA. It founds the principles and specifies the actions for developing Type III environmental declaration programmes and declarations and forms the use of the ISO 14040 series in the development of the programmes and declarations. Type III environmental declarations, as defined in this standard, are primarily meant for business-to-business communication. Under certain conditions, however, their use in business-to-consumer communication is not excluded. Type III environmental declarations are defined as: "claims which indicates the environmental aspects of a product or service, providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information". (ISO 2006a.)

The ISO standards 14040:2006 (Principles and framework) and 14044:2006 (Requirements and guidelines) are the main standards guiding LCAs. The ISO 14040 gives an overview of the LCA (practice, applications, limitations) to a wide range of potential users and stakeholders with different levels of knowledge about LCA. The ISO 14044 is meant for the preparation, conduct and critical review of the LCI analysis. Further, it provides guidance for the LCA's impact assessment phase and for the understanding of the results of the LCA. In addition, there are also guidelines for the data collection. (Gasiorowski-Denis 2006.)

ISO 14064, parts 1 and 2, present tools for governments and industries for assessing and supporting GHG emission reduction and trading. (Bird 2006.) It is a standard for boundary determination, GHG emission quantification and removal, and GHG mitigation project designing. (Pandey 2011, p. 143.) As a whole, it is expected to provide clarity and consistency for organisations, governments, project promoters and other stakeholders around the world in the quantification, monitoring, reporting, validation (or verification) of GHG inventories and projects. ISO 14064-1 (Greenhouse gases -- Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals) includes requirements and principles for the quantification, design development, management, reporting and verification of GHG emissions and removals at the organisational level. (ISO 2006b.) ISO 14064-2 (Greenhouse gases -- Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements) gives specifications and guidance at the project level. The standard focuses on projects and activities that are designed to reduce GHG emissions or to increase GHG removals. It includes principles and requirements for planning a GHG project, for defining the project baseline scenarios, for identifying and choosing GHG sources, sinks and reservoirs relevant to the project and the baseline scenarios as well as for measuring, documenting and reporting on the performance of the project in relation to the baseline scenario. (ISO 2006c.)

ISO 14067 (Greenhouse gases -- Carbon footprint of products -- Requirements and guidelines for quantification and communication) addresses the GHG impact on only one category, climate change, and does not consider any other impacts rising from the life cycle of a product. It is based on the ISO 14040 and ISO 14044 about LCA for quantification of the carbon footprint of goods and services and on ISO 14020, ISO 14024 and ISO 14025 about environmental labels and declarations for communication of the results.

# 5 Conclusions of literature review

The rising awareness of climate change and its consequences, national and international goals, agreements and regulations as well as the pressure from stakeholders are all reasons for service oriented companies to take responsibly and act sustainably. Likewise, the environmental impact of service oriented companies cannot be overlooked. Traditionally the service sector has not been seen as having a great environmental impact. The activities of service company however, use resources (computers, furniture, travelling etc.). The sector can actually have a significant environmental impact, especially as it is a large and fast-growing sector economically. Even though a shift towards a more service-oriented economy may decrease the GHG emission intensity per unit GDP, the absolute emissions will grow.

Manufacture goods extensively used by the service sector is IT related equipment. The influences of IT on the environment can be both positive and negative. A digital service creation company like Futurice should consider and be aware of the environmental opportunities and threats related to IT. The literature review presents three approaches for greening of IT and four frameworks than can be used to identify Green IT and sustainable business process opportunities.

A comparisons and compilation of previous studies about the same topic showed that even though the absolute emissions vary depending on the characteristics of the company (size, location etc.), the assessment method and the availability of data, the percentage division of emissions between categories was similar. The studies had been using different LCA methods and for a screening LCA, with the objective to find the biggest emission contributors, all methods were found to be suitable. Based on the results it could be recommended that a service oriented company should focus on emission from the office premises, commuting and business travel. These categories generally generated the biggest environmental impacts. Similar results will be assumed for the case study.

The LCA framework is often seen as the most appropriate method for a comprehensive environmental assessment. The basic idea of a LCA is considering all environmental burdens, from raw material extraction to becoming waste, of a product or a service. It is important to recognise the limitations and uncertainties related to a LCA and try to avoid them. All recognised factors influencing the reliability of a performed assessment, that cannot be eliminated, should be listed.

The carbon footprint concept has become one of the most important indicators for environmental protection. Determining the carbon footprint is one way to estimate the impact on climate change, possibly the most recognised environmental impact of all. A comprehensive environmental assessment should include more than the impact only on climate change. This study will however focus on determining the carbon footprint due to its wide spread and established reputation.

How to perform the carbon footprint analysis is debatable. Traditionally the carbon footprint has been addressed using the PRO-LCA or the IO-LCA methods. In this study the IO-method and the hybrid method will be used. The hybrid method combines the benefits of a PRO-LCA and an IO-LCA. Further several standards and guidelines have been developed to help perform an LCA and GHG accounting. The GHG protocol is commonly used as a standard and accepted worldwide for guiding GHG accounting. This study will lean on the GHG protocol for guidance.

The importance of the behaviour of individual workers is also discussed. It cannot be denied that changes in the behaviour of individuals is needed for sustainable development to succeed. The effect of one employee may be small but together the effect of all employees is substantial. Studies have found that training, knowledge and the directors as role models are important factors influencing the motivation of employees to behave in more environmentally responsible way. This should be acknowledged by companies that want to change and encourage their employees to more environmentally sound behaviour.

# 6 Research design and methods

The aim of the case study is to determine the carbon footprint of a service oriented company and to find the most important activities and variables behind the emissions. The case study encompasses a personnel questionnaire (survey study) and three LCAs. The LCAs conducted are so called streamlined LCAs due to the limited scope of the study, only covering the impact from GHGs on climate change (Säynäjoki et al. 2017, p. 5). Further the LCAs can be termed "screening" LCAs as the purpose was to find the key activities causing emissions and mostly existing emissions data were used for the assessment (Lindfors et al. 1995 in Junnila 2004, p. 191). The results are presented as the company's carbon footprint, which uses carbon equivalents as the defined unit of measure. In all LCAs the GHG protocol was followed as a guideline.

The LCA standards, including the GHG protocol, suggests four main steps for an LCA report: (1) definition of the goal and scope, (2) boundary definition, (3) LCI and (4) LCIA and interpretation of the results (WRI and WBCSD 2004; Säynäjoki et al. 2017). Even though the results have not completely been presented in this way, all four steps are included. The goal and scope are presented in the beginning of the study (chapter 1.2), the boundary is discussed both in chapter 1.2 and chapter 6.1, the life-cycle inventory is presented in chapter 7.2 and 7.3 and the results are presented in chapter 7.4 and further discussed in chapter 8.1. The set up was found suitable for this study to be able to include all necessary information in a reasonable way.

## 6.1 System boundary and data

The case study system boundary is determined with the help of the GHG protocol. As mentioned in the literature review the standard has often been used when performing carbon footprint calculations. In accordance with the GHG Protocol Corporate Standard (2004) and the supplement GHG Protocol Scope 3 Standard (2011), the third scope (downstream activities) has also been included in the study. The company studied does not produce any physical products nor do they own any company vehicles, combustion devices or air-conditioning equipment (the premises are rented), hence they are not producing any direct, scope 1, emissions. Therefore, only scope 2 and scope 3 emissions will be accounted for. The protocol is designed to account for the six main GHGs, which in this study will be expressed by determining the carbon footprint as $CO_2$ equivalents.

The use of accounting records from the past year as the main data was assumed to give a reasonable level of detail for the study. All data, but commuting and premises related figures, are based on the accounting records from 2016. The accounting records was for both offices in Finland. The allocation for the Helsinki office was based on the share of employees in Finland located in Helsinki. From the accounting records, only figures where the use was very unclear or where they were assumed to not have an environmental impact from Futurice's perspective were left out. These costs are seen to be paid more as a symbolic rate or compensation than actually leading to an activity by the receiver. The costs left out are some particular rents, membership fees, donations, compensations, expense bookings and daily allowances. Together they stand for less than 15 % of the total costs in the 2016 accounting records and no activity alone stands for more than 6 % of the total costs. The commuting calculations are based on the personnel questionnaire and the data for premises are collected from the real estate manager. The emission factors were received from LCA databases, available local or national average statistics and from the service providers.

### 6.1.1 Impact assessment

A full life cycle impact assessment should include more than just the impact on climate change. To understand all impacts a service oriented company has on the environment additional impact categories would have to be included (e.g. health, acidification etc.). (Lindfors et al. 1995, pp. 35-37, 74-78; Finkbeiner 2009, p. 93). Carbon footprints, however, only determine the impact on climate change even though the framework builds on the life cycle approach. The aim of this study is to determine the carbon footprint of a service oriented company and hence only the global warming potential, expressed as $CO_2$ equivalents, is considered in this impact assessment.

## 6.2 Assessment models

Two existing IO-models have been used, to compare the impact of using country specific databases. One of the calculations was then further developed into a hybrid-LCA. There are several different types of hybrid-LCAs. This assessment rely heavily on budget data and hence the IO-based hybrid analysis describes this assessment best (Bilec et al. 2006, p. 209). In the hybrid-LCA the PRO-LCA was used for studying emissions from commuting and business premises. The PRO-LCA data for energy, waste, water and transportation all include both upstream and downstream emissions.

The accounting data was divided into five main categories: purchased services, activities within company, office equipment and supplies, building premises and travel. The division is based on the earlier research presented in the literature review (chapter 3.2), although the office equipment and supplies are combined into one category and the category activities within the company is added. As seen from earlier studies the office supplies generally have a relatively small impact and it was therefore not seen necessary to divide supplies and equipment into different categories. In addition, based on the accounting data and the characteristics of the company, it was found suitable to add the category "activities within company" as these activities where not seen applicable to add to any of the other categories. This category includes marketing, education, events, etc. For the sake of the case company it was most suitable to do the categories this way. Detailed information about the categories can be found in appendix B.

### 6.2.1 IO-model ENVIMAT

SYKE (Suomen ympäristökeskus) has in 2009 published a list of life cycle climate effects for 151 industries as part of the ENVIMAT project. The results are based on research determining the life cycle environmental impact for 151 industries, calculated with the help of 918 domestic and 722 imported products or services. As a part of the project an EE-IO (Environmentally Extended Input-Output) model was developed in order to be able to estimate the environmental impact from material extracted from the Finnish nature and imported material. Consumption-oriented studies are based on data presented as emissions per purchasing-price and includes, in addition to impacts caused by extraction of material and manufacturing, also the environmental impacts caused by trade and transportation. The data for consumption-oriented studies is organised into 52 sectors by the intended use of the product or service, according to the COICOP classification model (Classification of Individual Consumption by Purpose). (Seppälä et al. 2009.) Even though the ENVIMAT EE-IO model by SYKE is initially design for examining the consumption of households, the actions having environmental impacts in a service oriented company and a private household does not differ to such extent that the same data wouldn't be suitable for both purposes (Koivisto 2008, p.16). To the author's best knowledge, no earlier research has used the

ENVIMAT model for determining the carbon footprint of a service oriented company in Finland.

The data used to create the model is from 2005, therefore the 2016 accounting records have been discounted to correspond to 2005 prices, using the average inflation rates for Finland as the discounting rate (OFS 2017). Then the accounting record activites where matched to the 52 COICOP sectors ($3^{rd}$ level has 41 originally, but a few sectors where divided further in the research by SYKE). For more details about the matching of sectors see appendix B

### 6.2.2 EIO-LCA by Carnegie Mellon University

The second IO-LCA was performed using the database developed by the Green Design Institute at the Carnegie Mellon University (Carnegie Mellon University Green Design Institute 2008a). The data is available through an online tool, where the latest version uses monetary values from 2002. As this database has 428 sectors (based on NAICS), the level of detail is much greater than for the Finnish data with only 52 sectors. However, this data is based on manufacturing, material flows, transportation, trade etc. in the U.S. and was therefore assumed to give somewhat higher results. Especially the energy mix for electricity generation (see Chapter 3.2.4) differs between U.S. and Finland. In Finland renewable energy sources (mostly hydropower) and nuclear power, sources with very low emissions, are used for over half of the electricity generation compared to the U.S. where coal and natural gas (fossil fuels) are the biggest sources.

The EIO-LCA tool has two versions; the producer price benchmark model and the purchaser price benchmark model. The purchaser price model was chosen as the case company is seen as the purchaser of products and services, not the producer, in this study. The purchaser model accounts from “cradle to consumer”, including the whole economy until the delivery and distribution of the final product (or service) to the customer, compared to the producer model only accounting from “cradle to gate”. As the model is based on 2002 monetary values the accounting records are discounted from 2016 to 2002, using the same inflation rates as in the LCA with Finnish data and then converted into USD with the help of the purchasing power parity for Finland and the U.S. which in 2002 was 0,998. More detailed information about matching the accounting records to the sectors in the EIO-LCA can be found in appendix B

### 6.2.3 Hybrid LCA

The hybrid-LCA, as mentioned in chapter 4.3.3, combines the strengths of the PRO-LCA and the IO-LCA. To get an as accurate estimation as possible of the carbon footprint of the case company, a hybrid-LCA was performed to improve the IO-LCA made with the ENVIMAT model. Only the IO-LCA with Finnish data was further developed into a hybrid method, as using country specific data was seen as a more important factor than having a more detailed sector division provided by the U.S. based EIO-LCA model. The boundary between the IO-LCA and the PRO-LCA generally depends on the availability of data, requirements for the level of detail and accuracy and time, labour and money limitations (Suh et al. 2004. p. 661). The PRO-LCA method could not be used to as big an extent as hoped for because of lack of data. Business travel had to be estimated with the IO-method instead of the PRO-LCA, as there was not enough available data. Hence it was only emissions related to the office premises (energy, waste and water) and commuting that could be analysed using the process LCA method. The data for and process of the hybrid-LCA is further discussed in chapter 7.3.

# 7 Case study

This sector covers the personnel questionnaire, the carbon footprint assessment and a data quality and sensitivity analysis. The carbon footprint results are presented and briefly discussed. A summary of suggested possible improvements is included as well. All results are further discussed in section 8.

## 7.1 Company presentation

”We believe that the future is digital” is one of the slogans found on Futurice’s webpage. Futurice is a Finnish company that has made software since 2001 and through their innovative ideas they help customers change the way they work. The core of the business is the creation of both business to business and business to consumer applications and services for mobile,web and beyond. Around the core there are many levels of services offered to their customers, everything from analytics and continuous improvement for existing services all the way up to current state analysis, digital strategy consultancy and cultural change. The working culture is based on three core elements: transparency and trust, freedom and responsibility and self-improvement and social impact. Futurice finds transparency within the company important and believe that in order for people to take responsibility for their work, access to information is key. “Trust is given, not earned” as they say on their webpage. Responsibility comes with freedom and that makes it possible to fit work and private life together. Further, they compensate their employees for time they spent on open source projects and other activities with social impact as they want to encourage people to better themselves and the world.

Futurice has six offices in four European countries, one of them in Helsinki, which is the focus of this study. In the Helsinki office there were 278 employees at the time of the study. The office, located in the heart of central Helsinki, is rented. For now, Futurice does not have any CSR-like plan or report. Employees have however been concerned about the company’s environmental impact. Futurice decided to take their environmental responsibility forward and determine their environmental impact through carbon footprinting. The goal was to map out the emissions caused by the business activities to be able to manage the company’s impact on the environment. Possibly in the future they will aim for an environmental certificate.

## 7.2 Personnel questionnaire

A commuting, energy usage and recycling habit questionnaire was carried out among the Futurice personnel at the Helsinki office, in June 2017. The survey was made as an online questionnaire to make the process efficient and to reach out to as many employees as possible. Of the 278 employees 101 answered the survey, which represents 36 % of the office and it was assumed that this can reliably represent the whole office. The aim of the questionnaire was to analyse the employees’ commuting, energy usage and recycling habits and how satisfied the employees are within these areas. The questions were formed to ask about habits rather than tracking e.g. a week, in order to avoid the time of the survey and exceptional circumstances to influence the results. The survey can be found in appendix A. Next the questions and results will be presented in more detail by themes; commuting, teleconferencing, energy usage and recycling. In general, the results were better than expected regarding the employees’ interest toward sustainability issues and actions.

The results are used to establish the environmental responsible behavior among the employees. The commuting habits results are used to determine the carbon footprint of commuting. Moreover, the results are helpful to find out where and what kind of environmental related improvements could be made, which was one of the goals of the study. It also shows how willing employees are to change within certain areas, which gives an indicator of how much effort Futurice would have to put in the different areas to get the employees to behave more environmental responsible. The less willing the greater efforts are needed from Futurice's side.

### 7.2.1 Commuting

Earlier studies show that commuting can be one of the biggest impact categories GHG emission wise for service oriented companies (see chapter 3.2) and is hence the most relevant part of the questionnaire. In the questionnaire, the employees were asked to estimate their distance to work and what kind of transportation they on average use during a normal week. It was separated into summer / spring and winter / autumn due to the big weather differences

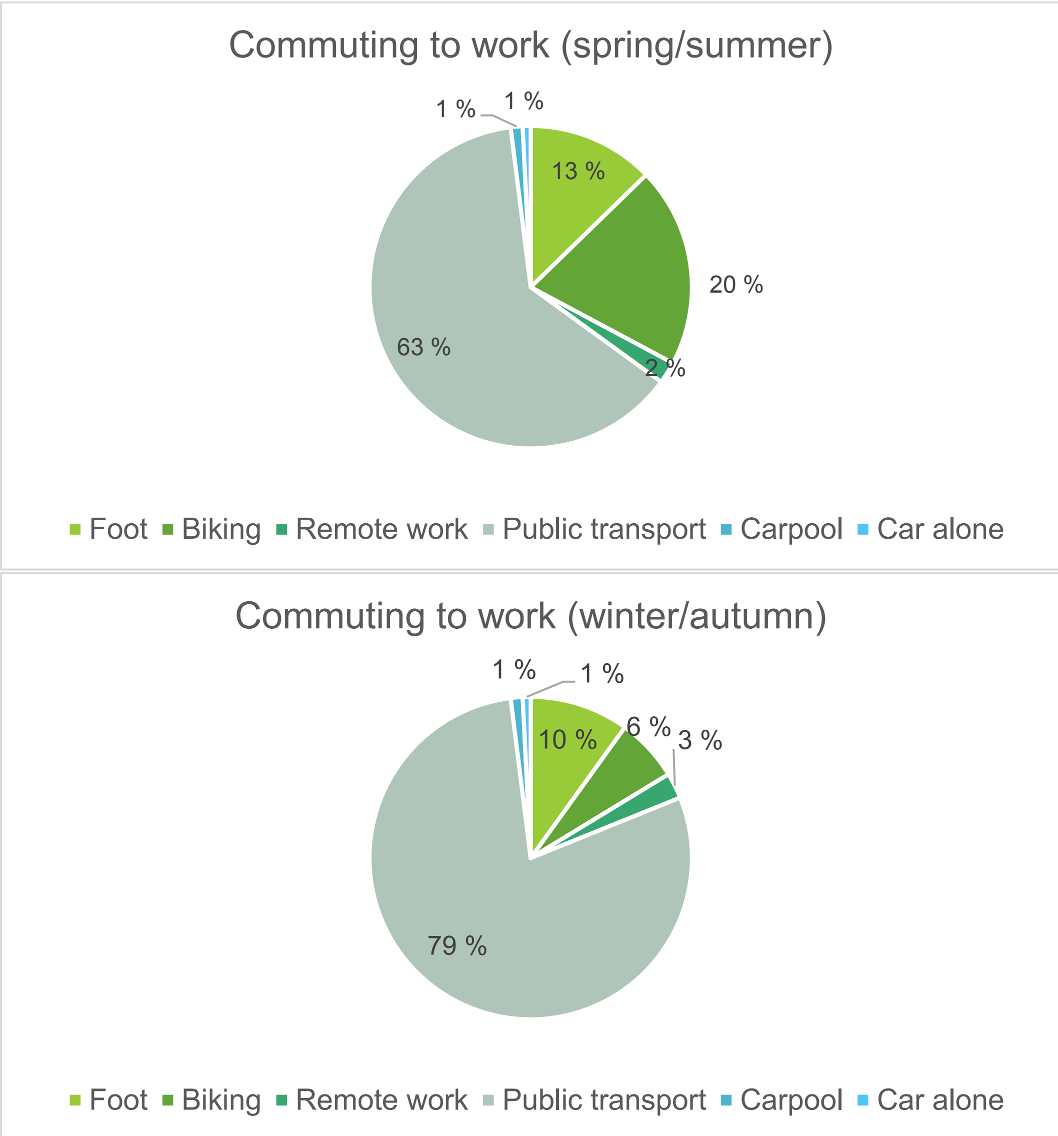


*Figure 21 Commuting habits during an average week. Figure 21a describes the percental division between the used transportation options during a week in the winter / autumn and figure 21b during summer / spring. To clarify it means that e.g. during an average week in the winter 79 % of the commuting trips are done by public transport.*

by season in Finland. Further they were asked to estimate how easily they feel that they could use more environmentally friendly commuting options.

From Figure 21a and Figure 21b, it can be seen that the commuting habits differ somewhat depending on the season. Public transport is the most common way of commuting all year. Biking and walking increases during the spring and summer, reducing the use of public transport, which could be expected due to the changing weather conditions in Finland depending on the season. Private cars and car pooling are not very commonly used among the employees any time of the year. The results were not completely unexpected due to the central location of the office, in the heart of Helsinki, with good access to public transport. However, the use of private cars is even lower than expected which affects the carbon footprint in a beneficial way. Remote working is not very common, however, according to Shrake et al. (2013, p. 270) the environmental impact from commuting could be reduced by 4-10 % if 50 % would work one day a week from home.

Further people were asked to evaluate if they could use alternative, more environmentally friendly transportation options to a greater extent. If people found that they already use the alternatives as much as possible (e.g. 5 times a week on average), they chose the option “No, I already maximize my use”. This answer could also be chosen if the person though that he or she does not have the possibility to use the alternative more often (e.g. more than twice a week) due to personal reasons (e.g. very long distance to work, limited public transportation from home to the office, living so close to work that walking is the best option), even though it would be possible in theory. This means that choosing this option does not necessarily mean that this person is already commuting in an environmentally friendly way all week on average as the results are subject to personal interpretation. From Figure 22 we can see that almost 90 % think that they already utilise public transport as much as possible. A few commented that bus vouchers are a great way to encourage people to use public transport. Biking could easily be promoted according to the survey, almost 50 % think they could easily

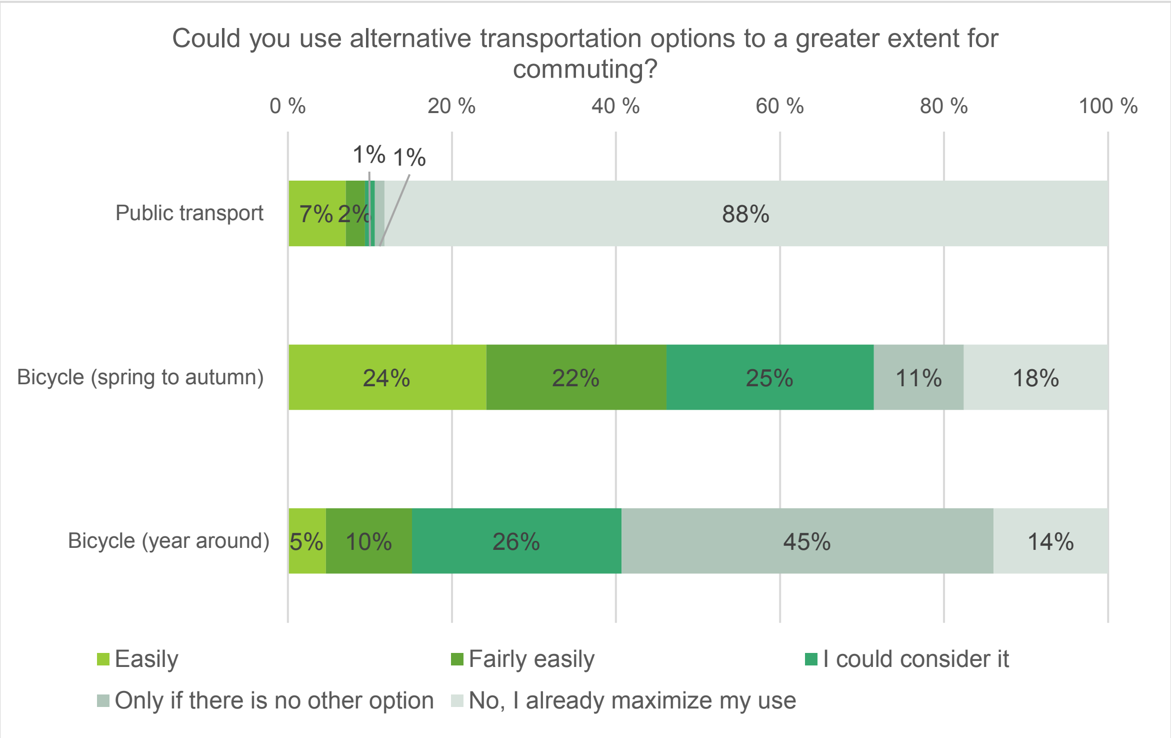


*Figure 22 People's willingness (possibility) to change commuting habits*

or rather easily bike more often to work from spring to autumn and 25 % could consider it. Not as many would be prepared to do it all year around, during winter as well, which is not surprising considering the weather conditions in Finland during the winter. To make biking a more attractive option employees would hope for better shower and changing facilities with storing and drying possibilities at the office. Also, the questionnaire showed that not necessary all know about the current shower and parking possibilities for bikers. Further, discussing with customers about the possibility for Futurice-employees to use their bike parking and social facilities was hoped for by many. The use of the Helsinki city bikes could be promoted e.g. through offering subsidies or voucher for seasonal tickets. Some other kind of compensation for bike maintenance or biking gears could encourage people to bike as well as a course in basic bike maintenance or in biking technique.

### 7.2.2 Tele- and videoconferencing

Futurice has six offices in different cities in Europe of which two are in Finland. Naturally employees will travel between the offices both abroad and within Finland as well as to customers offices when necessary. As described in section 3.2.5 (Transportation), travelling has a big impact on the environment and according to previous studies (chapter 3.2) travelling can be one of the biggest emissions contributors.

Tele- and videoconferencing (here on referred to as teleconferencing) is one way to decrease the amount of travelling. Digital communication services have come a long way and can today offer many possibilities for co-working on distance. Futurice is using teleconferencing to some extent and as can be seen from Figure 23, 9 % use it almost daily and nearly 40 % use it at least once a week. There is however a significant part using it very seldom or almost never. The employees were also asked to estimate the share of teleconferencing meetings out of all their meetings with people outside of the Helsinki office. The results varied all between 0 – 100 %, with an average of 32 %. The big variance can be interpreted as differences in the attitude towards teleconferencing. Some use it naturally and extensively while others perhaps are not fond of or do not know how to use the teleconferencing systems.

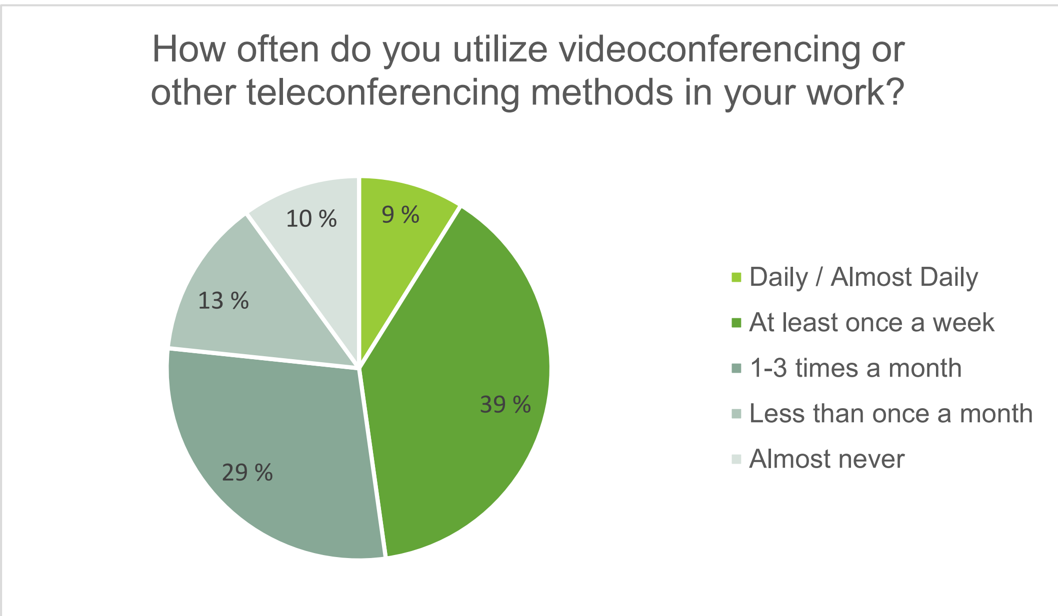


*Figure 23 Results of how often people estimate that they use tele- and videoconferencing in average*

In general, the employees are satisfied with the teleconferencing possibilities and over half are very satisfied or satisfied with the offered opportunities (Figure 24). Still, a noteworthy part is only moderately happy with the teleconferencing resources and there are employees who are dissatisfied and even very dissatisfied with the teleconferencing opportunities. People are mostly dissatisfied with technical solutions and find technical problems to be the biggest issue. Reported technical issues that should be looked over by Futurice are: poor connection, difficult equipment, issues with the sound and video quality and difficulties with getting the audio, microphone, video and screen sharing to work during a meeting. People get annoyed when it takes too long to set up a teleconference meeting and at always having to deal with technical issues, especially in the beginning of a meeting. This discourages the utilisation of remote meeting opportunities. Coaching in teleconference facilitation skills and technical education about the equipment were suggested measures for improving the ease of use. Another technical issue that was raised was the matching of systems with customers. Occasionally the customer uses a videoconferencing software that is not supported by Futurice which naturally prohibits the use of teleconferencing in that situation. This however, this is not an issue that Futurice solely has to assume responsibility for. Another obstacle mentioned is related to space. It can be challenging for the customer to find a suitable space at his or her office for having a teleconferencing meeting in, which of course is not a direct problem for Futurice to solve. However, the employees at Futurice have found it to occasionally be challenging to find an available room at the Future office. The employees aspired more small meeting rooms or spaces for teleconferencing alternatively equipment for teleconferencing in all existing meeting rooms.

Despite the enormous technical development and the overall satisfaction, people are not always very comfortable using teleconferencing. There were several comments pointing out that having a teleconference feels unnatural, uncomfortable and inefficient. From Figure 25 it can be seen that the employees are not very keen on using teleconferencing to a greater extent. Nonetheless, with the right tools and education it would be possible to motivate the employees to use teleconferencing, even a little bit more, if desired. Further many pointed

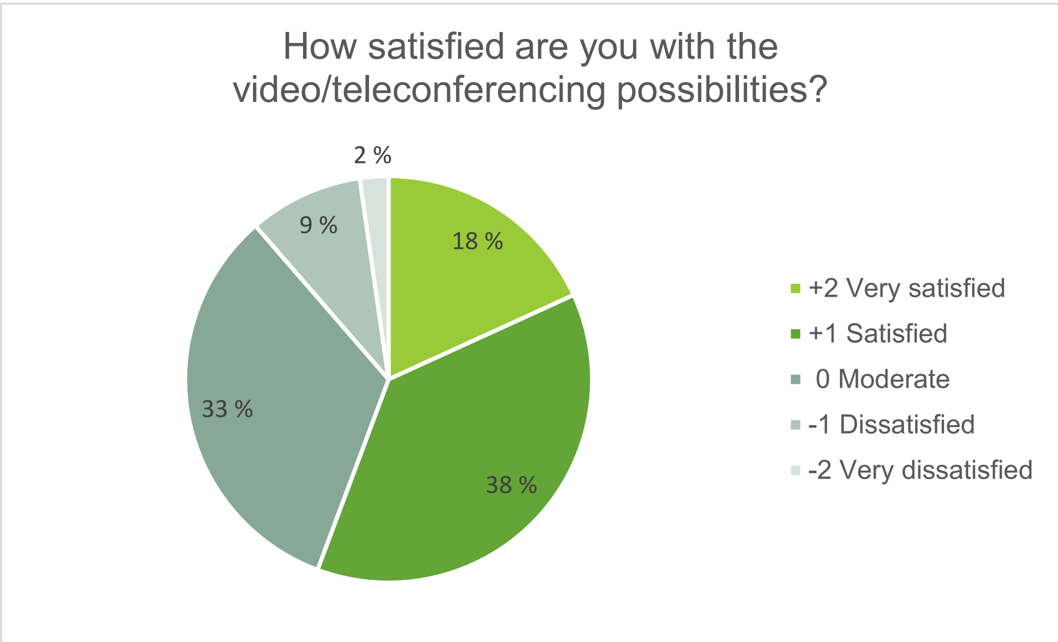


*Figure 24 The figure shows the satisfaction of the current opportunities offered for tele- and videoconferencing*

out that teleconferencing cannot live up to face to face meetings in person. It is not the aim to completely replace personal meeting with teleconferencing. The goal is to create awareness of the environmental benefits (possibly also economic) of teleconferencing, to start a discussion about the subject and to gather feedback from the employees regarding the subject.

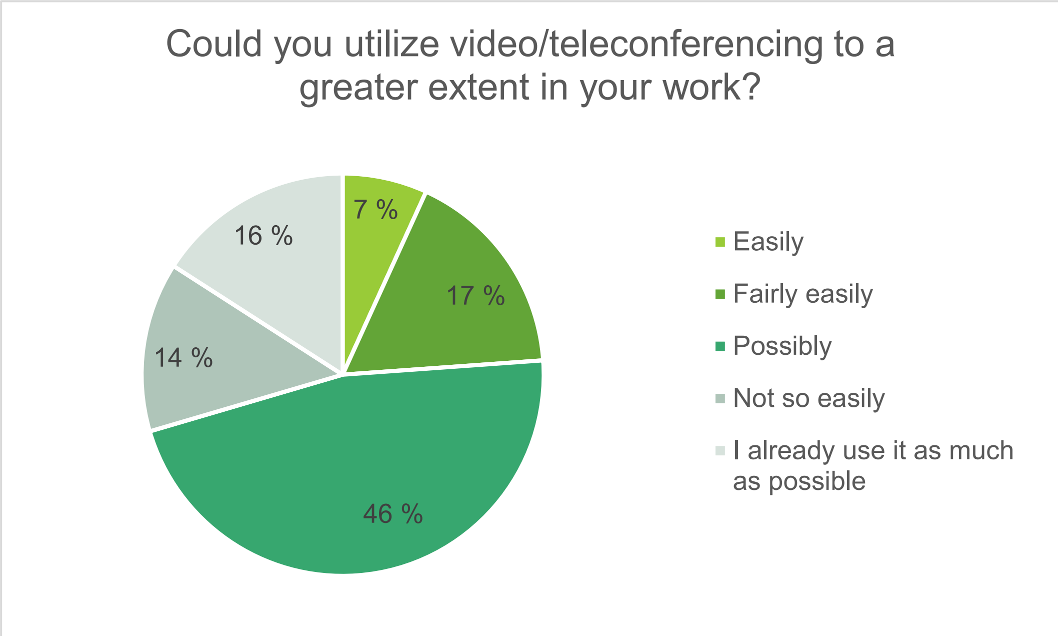


*Figure 25 The employees do not find in very easy to increase their use of teleconferencing in their work.*

### 7.2.3 Office equipment energy

Office equipment energy consumption was a minor part of the questionnaire, where the aim was to see what the employees do with their computers when not in use. The question was asked to see if there was any improvement to be made in this specific area. The questionnaire show that the employees have very good habits regarding energy usage of computers. There is not much room for improvement since 55 % replied that they turn off the computers when they leave their workspace and nearly 40 % that their computers go in sleep mode after maximum 15 minutes (Figure 26). The question was asked separately for laptops and desktop computers, though over 80 % informed that they do not own a desktop computer which made the results insignificant. Reliable information about the environmental impact of the use phase of a laptop is not easily found. The results vary a lot depending on the analysis. According to Ruth (2011, p. 210) a PC in idle state uses 60 W but only 5 W of power in energy save mode. The power saving initiative (screen brightness to 30-50%, sleep mode monitors after 5 min, computer after 7 min) implemented in the case studied by Shrake et al. (2013, p. 270) showed a decrease in the energy consumption by 15-20 %. This equal annually about 4 000 kWh hence a payback of less than three years for the labour of implementing the power settings.

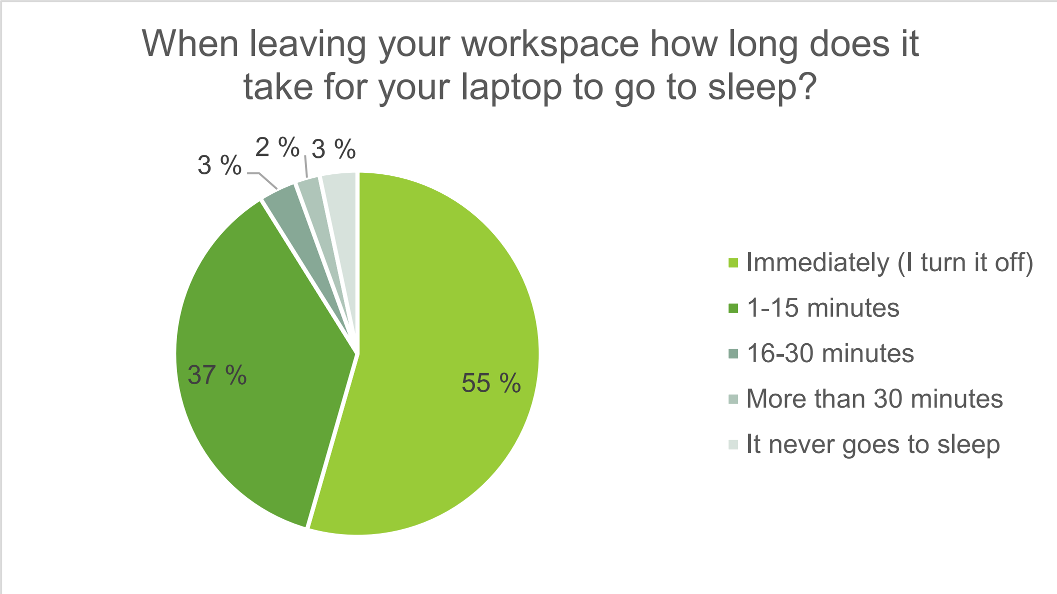


*Figure 26 The figure shows the average time it takes for the computers of the employees to go to sleep mode. The majority turns them off when not using them actively which is a good habit and reduces unnecessary energy usage.*

### 7.2.4 Recycling

To find out if and how the employees recycle as well as how smooth they find recycling the questionnaire included a section about recycling habits. The results were somewhat better than expected, considering that people in general can find recycling complicated and difficult and therefore not doing it. Approximately 80 % answered that they always or almost always recycle waste that can be recycled (Figure 27). Cardboard is recycled to greatest extent and over 80 % are recycling paper and bio-waste. Glass and metal is probably not generated in large amounts and not from everyone at work, which could explain the lower levels of

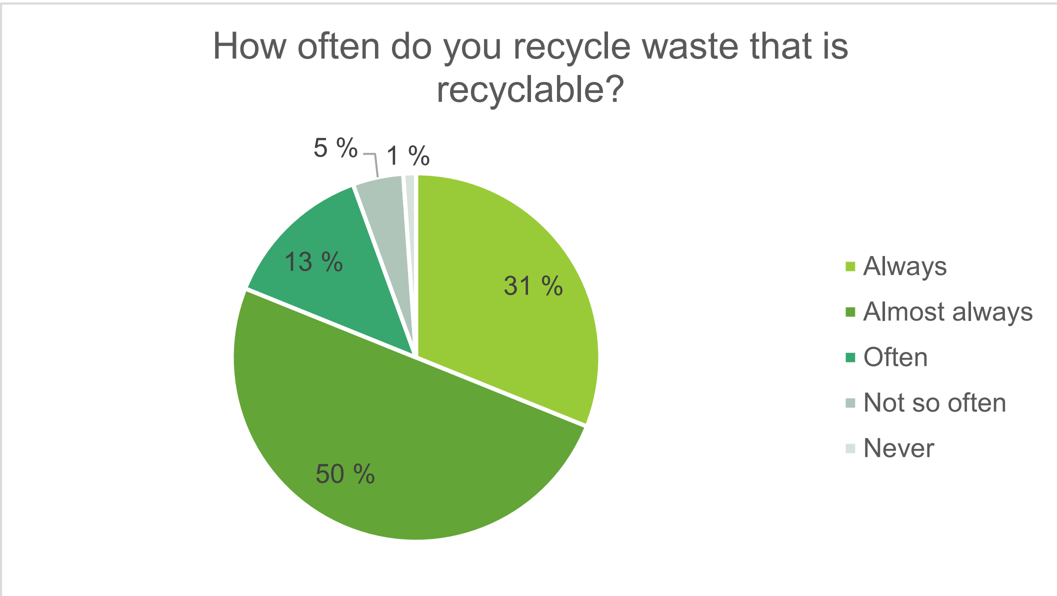


*Figure 27 The majority recycles every time or almost every time they throw away trash.*

recycling in these categories (Figure 28). Mixed (energy) waste and plastics are not separated. Electronic equipment is collected separately, but knowledge on what is done with it was not obtained.

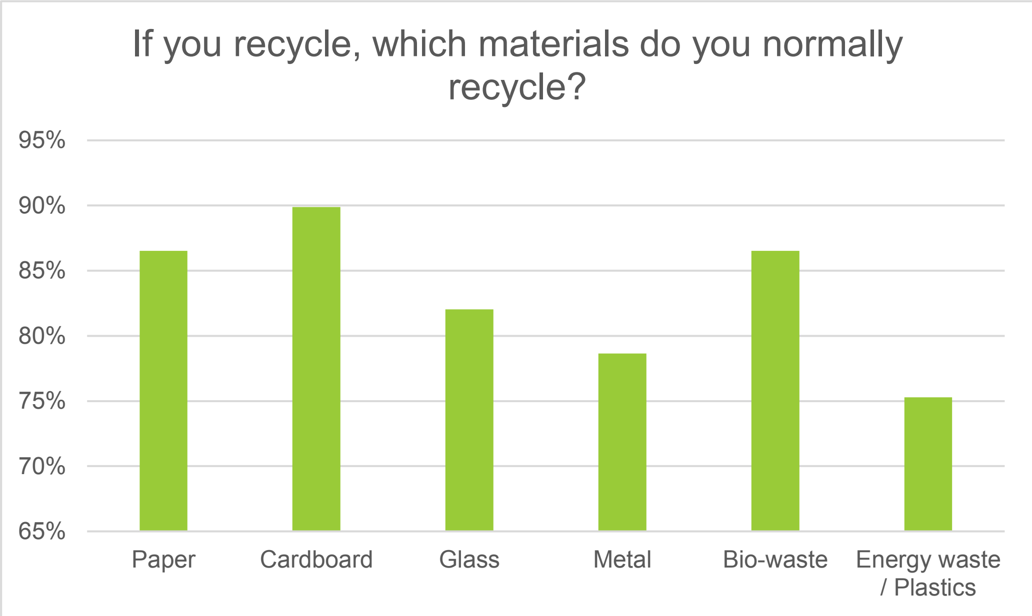


*Figure 28 Carboard, bio-waste and paper are the most normally recycled materials.*

Most of the employees, a bit over 70 %, find it very easy or easy to recycle in the office (Figure 29), which is a good sign. However, a significant part (almost 20 %) find it only relatively easily to recycle and 10 % even difficult or impossible. Hence, there is room for improvement within recycling. The comments show that the biggest issues experienced was regarding knowledge on how to recycle and the number and location of different trash bins. According to the comments the waste bins, especially in the kitchen, are often full, leading to people throwing waste in the ones that are emptier even though it would be the wrong one, e.g. plastic in bio. The disposal of the coffee grounds was mentioned several times and adding a bio-waste trash next to the coffee machine, together with signs and informing,

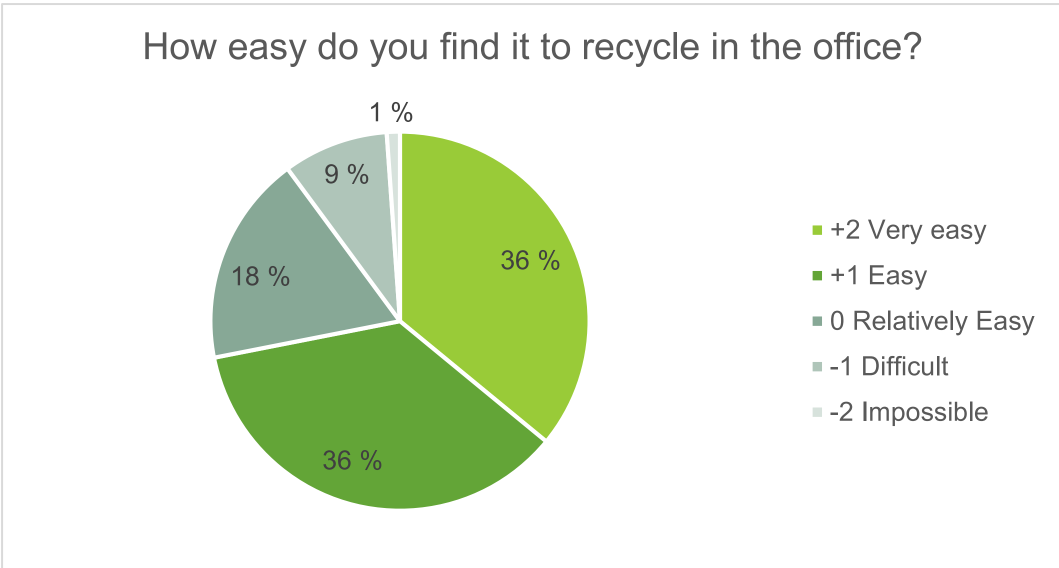


*Figure 29 In general the employees find it easy to recycle at the office*

would most probably increase the recycling of them. Further the comments showed that people are not aware of all the recycling possibilities at the office and that correct recycling is not very straightforward for everyone.

Signs, informing and education in this subject could help the employees recycle not only at the office but also outside the office, making it a greater deed than only improving the recycling and overall environmental performance at Futurice. With more knowledge recycling could be made a smooth and effortless process instead of feeling confusing and complicated. Further the location of trash bins raised comments, especially regarding bins in the wings and paper and cardboard collection. Employees find it difficult and inconvenient to recycle in the wings of the office and further paper collection in working areas and in the office wings was suggested. Paper is now only collected at one location in the office. Cardboard collection does not seem to be very upfront based on the comments even though 90 % stated that they normally recycle cardboard. There were numerous comments about improving the carboard collection. At the present cardboard is only collected in a separate room that everyone does not seem to know about.

Many were concerned about the amount of disposable used and especially the number of disposable cups that are used at the office. Directly implicating that disposable cups are worse than reusable cups is not as straight forward as one would think. The environmental impact depends on many things; material, energy for production, transport etc. Further the reusable cups are washed, which in turn uses energy that is not used by disposable cups. In the long term, if a reusable cup is used over 15-40 times (depending on the material), it has been calculated that it is less energy intense than a paper cup. However, the foam cup has been calculated to be as energy efficient as reusable cups (Figure 30). (Hocking 1994; ILEA, 2002). Woods and Bakshi (2014) though criticise earlier LCAs made on this topic and argues that one of the biggest shortcomings of Hocking's analysis is the assumption of the cup size (8 oz, while the average size in U.S is around 16 oz). Further they criticise that previous analysis have used a national average for power generation which affects the results. The key findings of the study made by Woods and Bakshi is the superiority of reusable cups

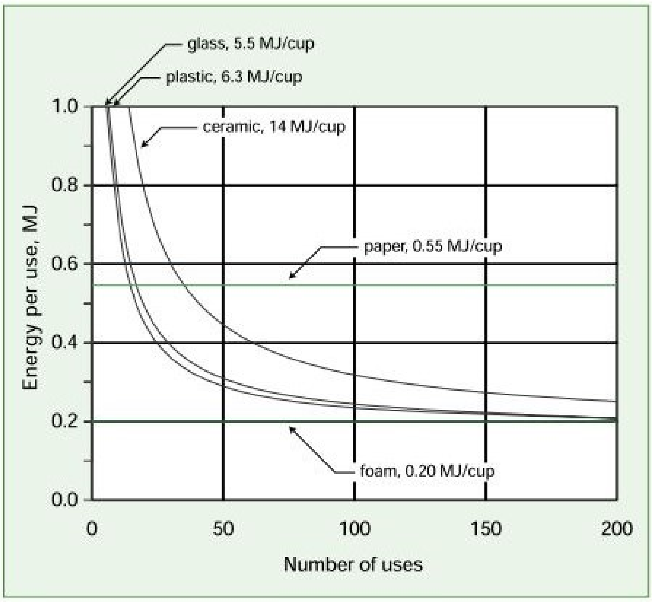


*Figure 30 Energy per use of each type of cup. The energy for the disposable cups is constant as it represents only the manufacturing energy sine they are used only once and never washed.*

regarding climate change, compared to disposable cups, in most regions in the U.S. Hence, assuming a typical serving size and washing in a standard-sized dishwasher after every use, the reusable cups are a better choice than both paper and foam cups. (Woods and Bakshi, 2014, pp. 931-932,939)

Recycling is important, and it can have positive environmental, economic and social impacts (see chapter 3.2.6 about recycling). The success of recycling depends on the participation of individuals throwing the trash. Knowledge about recycling and environmental issues as well as the feeling of convenience in general have a great impact on recycling behaviour. (McCarty and Shrum 1994, pp. 53-58.)

### 7.2.5 Summary personnel questionnaire

The personnel questionnaire shows that the location of the office and generally young employees affect the commuting habits in a positive manner. Seldom are as few persons, as the questionnaire demonstrates, coming by car to work and as many by public transport and bike. Cars are though not necessarily worse than using the bus (see chapter 3.2.5). Public transport does not however only incorporate bus but also rail transport (tram, metro and train), which cause less emission than cars. The questionnaire did not specify which kind of public transport that was used. Improvements could hence still be made, especially to increase biking but also to promote a less emitting car fleet and travelling by rail rather than by bus. At Futurice the situation is maybe not the more normal one, where it is attempted to turn car usage into the usage of more public transport. It is the next step, trying to motivate people to walk and bike instead of using public transport (or car for that matter). There were many suggestions for improvements that could be made for bikers.

Tele- and videoconferencing divides the employees. About half of the employees use it regularly and are satisfied with the possibilities while the other half think it is complicated and feel uncomfortable using it. Over half of the respondents think that they could consider using it more. With the right education and tools, the use of tele- and video conferencing could be made a user-friendly and appealing alternative.

Habits related to energy consumptions of computers were found to be efficient. Laptops are mostly used, in lieu of desktop computers which are more energy consuming. Employees also have a habit of turning off the computers when not used, saving energy.

The recycling habits vary somewhat, however the majority consider them self always or almost always recycling. Even though most experience the recycling to be easy to recycle a noteworthy part are not satisfied with the arrangements. Further the comments demonstrated that employees are not aware of all the recycling possibilities at the office. With small investments and training recycling could be made easier and the recycling habits could be improved.

Further discussion regarding suggestions for possible improvements are presented in chapter 7.5.

## 7.3 Carbon footprint research process and data

Data for the carbon footprint calculation, in accordance with the system boundaries, was collected either on monthly or yearly basis. Both cost and process (when accessible) data were collected. The source for cost data was the company’s accounting records from the previous year. Process data was gathered from the real estate manager and from the personnel questionnaire. The carbon footprint covers one operational year of the company.

To calculate the GHGs from each activity unit emission factors are needed. The GHG protocol recommends to use local emission factors. If not available national or global factors can be and are often used. The emissions for the IO-LCA are directly taken from the two utilised IO- models' databases. Process LCA emission factors used in this study are primarily statistical local and national emission factors or factors announced by the service providers.

IO-LCAs are based on monetary values from the accounting records and associated emissions data from the IO-models. Data used for the process LCA is further discussed in the next chapters. The system boundaries and assessment models have been presented in chapter 6 and the results are presented in chapter 7.4.

### 7.3.1 Energy and water

According to the GHG protocol Corporate Standard, scope 2 emissions should be included in the calculations. The scope 2 emissions account for indirect GHG emissions caused by the generation of purchased electricity, heat or steam that is consumed by the company. Energy and water consumption data for the whole building was received from the real estate manager. It was assumed that Futurice use energy and the water according to their share of the building area. Säynäjoki et al. (2011) suggest also including the indirect emissions from electricity production with the help of the IO-LCA. However, the ENVIMAT model does not provide as detailed result data about the sectors as does the Carnegie Mellon model used by Säynäjoki et al. (2011), hence data about indirect emissions is inaccessible for this hybrid-LCA. Unit emission data for electricity, heating and cooling was attained from the database One Click LCA (2017) by Bionova. The electricity unit emission factor is a Finnish average from the years 2007-2015 and the district heating factor is an average for Helsingin Energia for the years 2011-2015. For district cooling the only available value was from 2011. All energy emission factors used by the online tool include both upstream and downstream emissions. Unit emissions for water include the emission from production, distribution and wastewater treatment and were obtained from HSY (2017a) and is an average for 2009-2015. The energy and water consumption and the unit emissions data are presented in Table 9.

*Table 9 Energy and water consumption and unit emissions used in the study*

| **Energy & Water** | Eletricity | District heating | District cooling | Water |
|---|---|---|---|---|
| Consumption(1) | 140 MWh | 198 MWh | 67 MWh | 521 m3 |
| Emissions factor | 218 (2) gCO2eq./kWh | 233 (2) gCO2eq./kWh | 67 (2) gCO2eq./kWh | 643 (3) gCO2eq./m3 |

(1) Building manager

(2) One Click LCA (2017)

(3) HSY (2017a)

### 7.3.2 Waste

Waste management is organised by the real estate manager at building level and it is up to the companies to collect and sort their waste properly at the office. In the building, it is possible to recycle the following waste components: bio, glass, metal, cardboard, paper, energy and mixed. The waste amounts are monitored at building level. Likewise, as for the energy consumption, it is assumed that Futurice generates waste, in all collected waste components, in proportion to their area of the building (9% that is). The unit emissions for waste management are obtained from an online LCA tool maintained by WWF (2017) called the Climate calculator. The emissions unit factors are based on the waste management calculations by HSY, which include emissions from the process and energy consumption of waste management as well as emissions reductions from sold energy and from using its own renewable energy. The waste amounts and unit emissions are presented in Table 10.

*Table 10 Waste amounts and unit emissions*

| Waste | Biowaste | Glass | Metal | Cardboard | Paper | Energy waste | Mixed waste |
|---|---|---|---|---|---|---|---|
| Tons (1) | 2,70 | 0,31 | 0,15 | 0,87 | 0,34 | 3,12 | 3,63 |
| Emissions factor gCO2eq./kg (2) | 60 | 570 | 130 | 70 | 1050 | 636 | 410 |

(1) Building manager

(2) WWF (2017)

### 7.3.3 Commuting

In the personnel questionnaire (for more details see chapter 7.2.1) commuting habits were mapped out and divided into summer/spring and winter/autumn commuting due to the seasonal weather conditions in Finland. The commuting distances for the company were calculated based on the questionnaire. A similar division between the used transportation options as in the questionnaire, was assumed for all employees. With the help of the average distances and the total trips made in a year the total kilometres were calculated for the different transportation options. The division between the total number of trips in summer and winter was made equally and it was assumed that employees work 48 weeks per year (4 weeks of holiday). The unit emission factors per transportation option were acquired from the public database LIPASTO, which include the upstream and downstream emissions from fuels. It was assumed that cars owned by the employees are not older than 10 years, and therefore the average emission (g/km) was calculated from 2006-2016 (EURO 4- EURO 6). The emissions for carpooling is set to half of the average emissions for the car, assuming two passengers in the car. Public transport is assumed to be travelled by bus and the emission factor used is the average emissions calculated in 2016 given in $gCO_2eq.$ per passenger kilometre. (VTT, 2017.) It is presumed that biking, walking and remote work does not cause any emissions. The calculated kilometres per transportation option and the emission factors are presented in Table 11. The average kilometre per person is 3993 km/person/year, in previous studies the average commuting kilometres were found to be 4465 - 10 200 km/person/year (Junnila 2006a). This would suggest that employees on average live closer to the office than in the previous cases.

| Commuting | Emission factors (1) | WINTER km/year (2) | SUMMER km/year (2) |
|---|---|---|---|
| Car | 190 g/km | 8448 | 8448 |
| Carpool | 95 g/km | 27720 | 27720 |
| Public transport (bus) | 53 g/pkm | 557982 | 479679 |

(1) LIPASTO (2017)

(2) Personnell questionnaire (2017)

*Table 11 Commuting kilometers and emission factors*

### 7.3.4 Inventory analysis

The data for the activities of the service oriented company was gathered according to the system boundary for the operational year 2016. The primary source for the costs are the company's accounting records from 2016. For the process data, the primary resources are the real estate manager and the personnel questionnaire. Process data was gathered for all activities for which process data was available. It was aspired also for business travel but in the end, it was not available. Table 12 represent the inventory table and summarises the functions included and analysed in the assessment. It shows the source of the data and the type of data gathered. The costs are presented as the percentage of the costs assumed to have an environmental impact. The activities and corresponding costs are not included in any way in the calculations.

The emission factors for the different activities are needed to calculate the total GHG emissions of the company. There are many different actors providing emissions factors (e.g. energy producers) and additionally there is an assortment of available tools, databases and applications with their own emissions factors. It is up to the practitioner to choose the emission factors, which can either be LCA- or normal emission factors. As already mentioned the GHG protocol recommends to use local emissions factors. The emission factors for the activities assessed with the PRO-LCA are discussed in the previous chapters. They are gathered from the service providers, from national databases and from an online LCA tool with national and local data. For the activities estimated with the help of the IO-LCA the emission data is taken from national the ENVIMAT IO-model.

*Table 12 Inventory table. Costs presented as the percent of the costs assumed to have an environmental impact.*

| Category | Method | Cost (%) | Amount | Source |
|---|---|---|---|---|
| **Building premises** | | **18 %** | | |
| *Electricity* | *PRO-LCA* | | *140 MWh* | *Real estate manager* |
| *Heating* | *PRO-LCA* | | *198 MWh* | *Real estate manager* |
| *Cooling* | *PRO-LCA* | | *67 MWh* | *Real estate manager* |
| *Water* | *PRO-LCA* | | *521 m3* | *Real estate manager* |
| *Waste* | *PRO-LCA* | | *11 ton* | *Real estate manager* |
| *Maintenance and repair* | *IO-LCA* | *5 %* | | *Accouting records* |
| **Business Travel** | | **14 %** | | |
| *Travel* | *IO-LCA* | *9 %* | | *Accouting records* |
| *Accomodation* | *IO-LCA* | *3 %* | | *Accouting records* |
| *Other* | *IO-LCA* | *1 %* | | *Accouting records* |
| **Commuting** | | | | |
| *Car* | *PRO-LCA* | | *8 448 km* | *Personnell questionnaire* |
| *Carpool* | *PRO-LCA* | | *27 720 km* | *Personnell questionnaire* |
| *Public transport* | *PRO-LCA* | | *557 982 km* | *Personnell questionnaire* |
| **Activities within company** | | **21 %** | | |
| *Marketing* | *IO-LCA* | *8 %* | | *Accouting records* |
| *Events and entertainment* | *IO-LCA* | *8 %* | | *Accouting records* |
| *Other* | *IO-LCA* | *5 %* | | *Accouting records* |
| **Office equipment and supplies** | | **19 %** | | |
| *IT-equipment* | *IO-LCA* | *12 %* | | *Accouting records* |
| *Food and drinks* | *IO-LCA* | *5 %* | | *Accouting records* |
| *Other* | *IO-LCA* | *2 %* | | *Accouting records* |
| **Purchased services** | | **29 %** | | |
| *Insurances and health* | *IO-LCA* | *5 %* | | *Accouting records* |
| *Data and telephone related costs* | *IO-LCA* | *18 %* | | *Accouting records* |
| *Other* | *IO-LCA* | *6 %* | | *Accouting records* |

## 7.4 Results

In this chapter, the results of the carbon footprint calculation are presented and briefly discussed and compared to previous studies and to the pure IO-LCAs. The results are demonstrated as total emissions and emissions per employee. Further the relationship between costs and emissions are studied through the carbon intensity and efficiency.

### 7.4.1 Total emissions

The impact assessment shows that Futurice causes noteworthy greenhouse gas emissions in most categories. The carbon footprint for 2016, which represents a normal operational year for the company, is determined through a hybrid-LCA. The total emissions are 1368 $tCO_2eq$. This equals 0,03 % of the Helsinki Metropolitan Area's total emissions in 2016 (HSY, 2017b). The emissions can also be expressed as equalling approximately 7,2 million kilometres by car, which is almost 180 laps around the equator. The carbon efficiency and intensity are discussed further in the following chapters. The total emissions per category are summarized in Table 13 and Figure 31.

Business travel causes most of the emissions, 29 %. The impact from business travel includes all activities related to business travel, both actual travelling, accommodation and other related services e.g. travel arrangement services. The methods used to determine the impact was IO-LCA due to lack of process data (kilometres of the business trips). This leads to considerable uncertainty about the results due to the aggregation error of the IO-method. More detailed information can be found in Table 12 and Appendix B. The company has offices in several destinations in Europe and travels between these as well as to customers within Finland. Commuting on the other hand only causes 5 % of the emissions and is the category having least significant impact. The office is located at a very central location with good connections by public transport. Most of the employees travel by public transport and the second and third most used options are biking and walking to work. The building premises, including energy, water and waste management, has the second lest impact, standing for 15 % of the carbon footprint. Of these, energy has the greatest impact, representing nearly 39 % of the premises emissions. Energy includes electricity, heating and cooling and generates approximately 81 $tCO_2eq$. Waste management generates approximately 4 $tCO_2eq$. Water usage, including water production and distribution and wastewater treatment, cause only 0,3 $tCO_2eq$. The rest is constituted by services related to the premises; cleaning, security and maintenance. Futurice's space usage is very efficient and there is on average only 5,25 $m^2$ per employee, compared to the average for offices in Finland which is 11 $m^2$/employee (Hytönen, 2016). This naturally decreases the environmental impact of the premises. Office supplies and equipment stands for 18 %, purchased services for 19 % and activities within the company for 14 % of the environmental impact. The main working tools at Futurice are computers and other IT-equipment, which also stand for the biggest emissions in the office equipment and supplies category. Other activities included in this category are food and drinks for personnel (lunch vouchers, coffee), presents (business and personnel) as well as administrative supplies (newspapers paper etc.). Software, upgrading and maintenance, causes most of the emissions in purchased services. Futurice organises a lot of events and these stand for most of the emissions in the category activities within the company. More detailed information of what is included in the different categories can be found in Table 12 and Appendix B. The results are compared to earlier research in chapter 7.4.4 to give a reference to the magnitude of the emissions caused by Futurice.

*Table 13 Total emissions of the company by activity*

| Hybrid LCA | tCO2eq | % |
|---|---|---|
| **Total emissions** | ***1368*** | ***100 %*** |
| Building premises | 210 | 15 % |
| Business Travel | 396 | 29 % |
| Commuting | 64 | 5 % |
| Activities within company | 198 | 14 % |
| Office equipment and supplies | 245 | 18 % |
| Purchased services | 256 | 19 % |

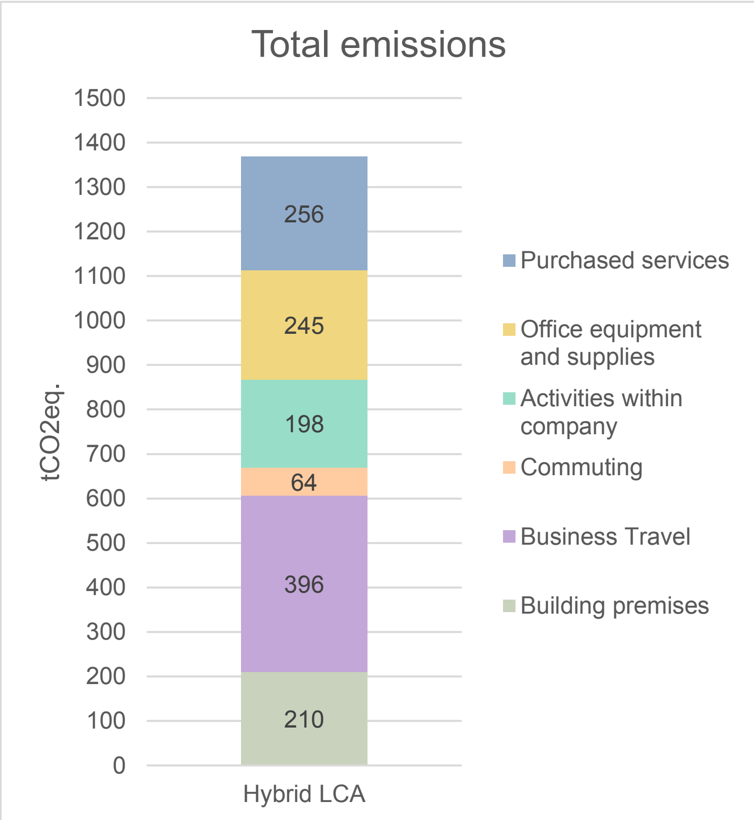


*Figure 31 Total emissions of the company by activity*

### 7.4.2 Carbon intensity per employee

Carbon intensity per employee is presented to enable comparison with earlier research. The overall carbon intensity is 4,92 $tCO_2eq$. per employee (Figure 32). In 2016 the average resident in the Helsinki metropolitan area emitted 4,3 $tCO_2eq$. (HSY 2017b). The average emissions per employee in previous studies are 7,4 $tCO_2eq$./employee. The percental environmental contribution naturally follows the same pattern as the overall emissions presented in the previous chapter.

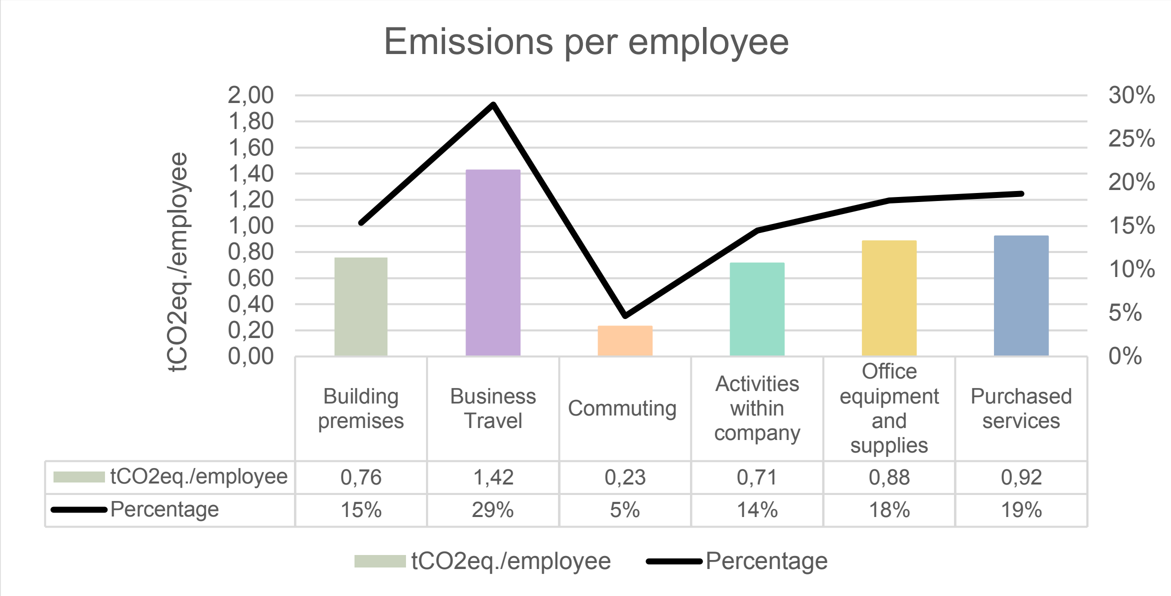


*Figure 32 Total emissions per employee by activity. Total emissions per employee are 4,92 $tCO_2eq$.*

### 7.4.3 Carbon efficiency and intensity

Carbon efficiency (€/$CO_2$eq.) and intensity ($CO_2$eq./€) expresses the relation between cost and emissions. Commuting is not inducing costs for the company and therefore the efficiency and intensity is determined for the category. Small carbon efficiency values are signs of inefficiency where relatively small costs cause big amount of emissions and vice versa. The overall average carbon efficiency for Futurice is 2,96 €/$CO_2$eq. The efficiencies of the categories are very close, though with business travel standing out from the group. The most carbon efficient category is purchased services, with a value of 4,14 €/$CO_2$eq. Standing for 29 % of Futurice's costs (that are assumed to have an environmental impact), it causes 19 % of the emissions. The least carbon efficient category is business travel with an efficiency value of 1,28 €/$CO_2$eq. Business travel generates 29 % of the emissions but stands for only 14 % of the costs. The carbon efficiency is presented in Table 14.

Carbon intensity implies the environmental impact per cost of the activity. Futurice's overall average carbon intensity is 0,37 kg$CO_2$eq./€. The intensity varies somewhat between the categories and the result is presented in Table 14 and Figure 33. In contrary to the carbon efficiency transportation has the greatest carbon intensity (0,78 kg$CO_2$/€) and purchased services the lowest intensity (0,24 kg$CO_2$/€). This implies that cutting costs in business travel could reduce the overall environmental impacts very efficiently while reducing costs in purchased services would not have an as big environmental impact.

*Table 14 The carbon efficiency and intensity of Futurice.*

| **Carbon efficiency and intensity** | Efficiency | Intensity |
|---|---|---|
| | € / kgCO2 | kgCO2 / € |
| ***Company total*** | ***2,69*** | ***0,37*** |
| Building premises | 3,11 | 0,32 |
| Business Travel | 1,28 | 0,78 |
| Commuting | N/A | N/A |
| Activities within company | 3,87 | 0,26 |
| Office equipment and supplies | 2,85 | 0,35 |
| Purchased services | 4,14 | 0,24 |

Table 14 shows both the carbon intensity and efficiency of Futurice. Commuting is assumed not to cause any cost for the company, but the emissions are included in the intensity and efficiency estimation. The commuting emissions are however relatively small and distortion of the indicators for total efficiency and intensity because of this is trivial.

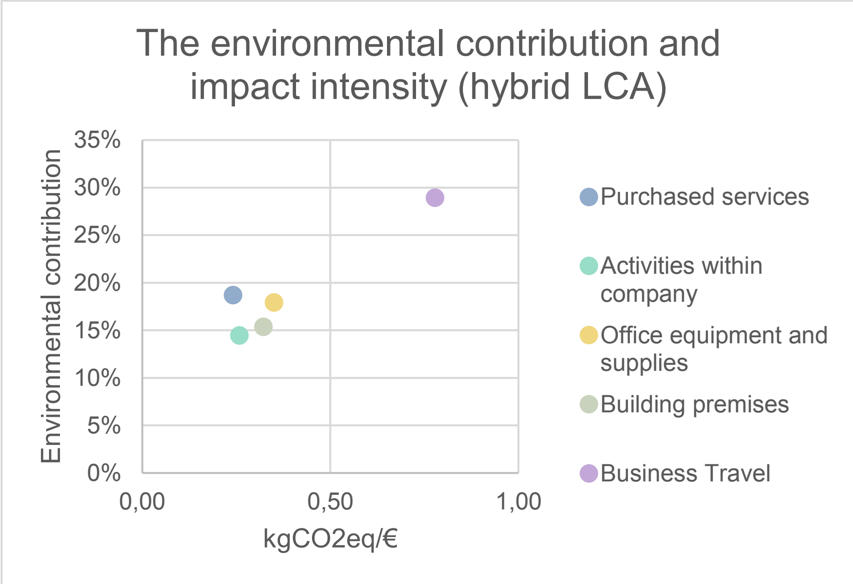


*Figure 33 The environmental contribution and intensity of the activities.*

### 7.4.4 Comparison to earlier research

Compared to earlier research presented in chapter 3.2 the carbon emissions per employee is in the lower end. The median results of the previous studies are presented in Figure 34 and the total emissions per employee range from 3,1 to 21,2 $tCO_2eq$. Note that the division into categories in the previous studies does not completely correspond to the categories in this study. In this study office equipment and supplies are combined to one category and an additional category, activities within the company, is added. Especially Futurice's office premises are very efficiently used (0,76 $tCO_2eq$./employee) compared to previous studies where the emission per employee ranged from 1,4 to 7 $tCO_2eq$. Business travel has the biggest impact from Futurice's side (1,42 $tCO_2eq$./employee). In previous studies (where commuting and business travel is separated) business travel stands for 0,05 to 4,5 $tCO_2eq$./employee. Combining business travel and commuting Futurice's emissions per employee are 1,65 $tCO_2eq$. and previous studies results vary between 0,1 and 6,7. Office supplies and equipment vary between 0,1 and 1,9 $tCO_2eq$./employee in previous studies. Futurice's emissions from this category lies almost midway between these with 0,88 $tCO_2eq$./employee. The added category corresponds best to the category purchased services in the previous studies. Combining these two categories from the case study results would result in 1,63 $tCO_2eq$./employee. The emissions from purchased services vary a lot in the previous studies, from as little as 0,1 up to 10,2 $tCO_2eq$./employee.

A more thorough comparison of the results can be find in the discussion part, chapter 8.1.

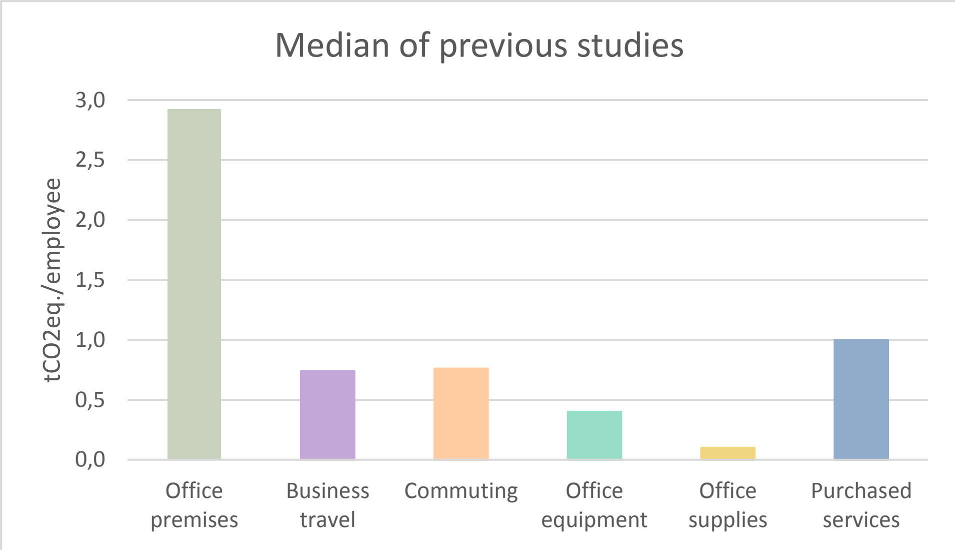


*Figure 34 Median impact from previous studies presented in chapter 3.2*

### 7.4.5 Comparison to conducted input-output LCAs

The hybrid-LCA gives very similar results compared to both the IO-LCAs. This is because the hybrid-LCA was mainly based on IO-data due to lack of process data. Commuting was not accounted for in the IO-LCAs as it does not cause any costs for the company.

The two IO-LCAs performed give very similar results. With the model provided by the Carnegie Mellon University, the results are 5,1 $tCO_2eq$./employee and 1420 $tCO_2eq$. in total. The results using the ENVIMAT model are 5,0 $tCO_2eq$./employee and a total of 1390 $tCO_2eq$. The results are presented in Figure 35 as $tCO_2eq$. per employee. The sector for electric power generation and supply is within the top five sectors for all categories in the Carnegie Mellon tool (similar information is not available for the Finnish data), see Table 15. Considering the different energy mixes (see chapter 3.2.4) in the two countries it was not expected to get such similar results from the two tools. The Carnegie Mellon University tool gives higher results in only one category, business transportation. This is presumably due to the tool assuming transportation energy sources with higher emissions than in the ENVIMAT data base. The higher results in the other categories for the ENVIMAT model can at least partly be explained by the aggregation of sectors. Appropriate sectors where not found for all accounting data and e.g. almost all services are presented by the same sector in ENVIMAT. The U.S data base has 428 categories to choose from while the Finnish database only has 52, making it possible to choose more fitting and detailed categories in the U.S. tool. Moreover, the ENVIMAT model is initially aimed for emissions calculations of private households while the U.S. data is for any purchaser. However, the activities and actions having an environmental impact in a service oriented company are almost identical to those in a private household (Koivisto 2008, p. 16).

Both the division between the categories and the absolute emissions are similar for all tools. The results show that for a screening LCA with the aim to determine the biggest impact categories, all methods are applicable. In addition, the U.S. data base can be assumed to give

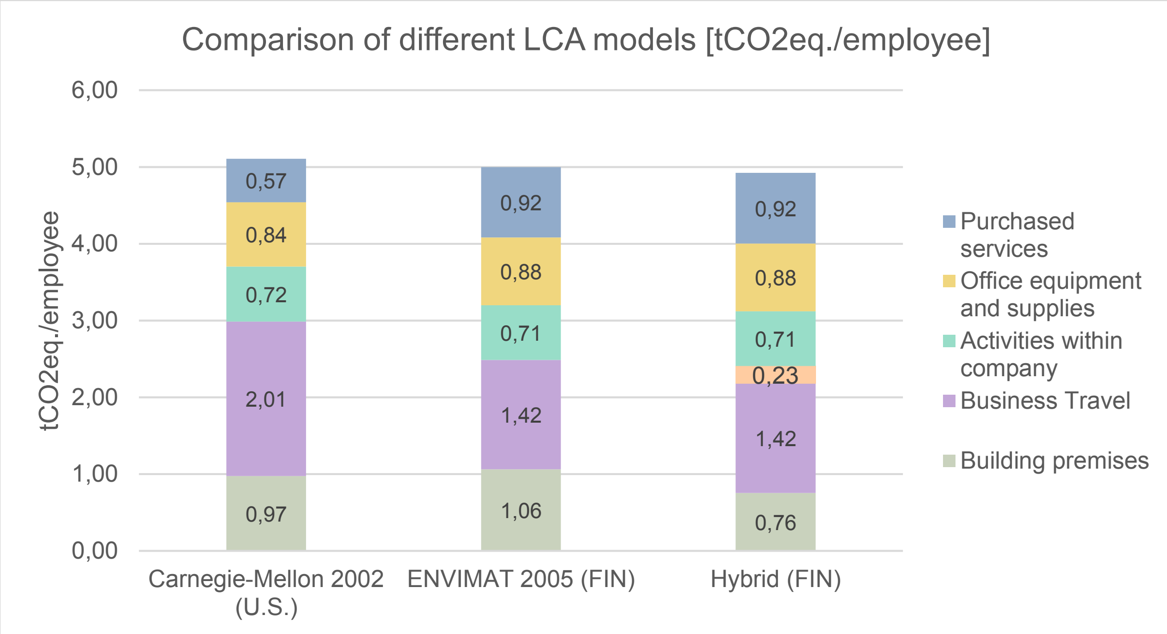


*Figure 35 Comparison of the results using three different LCA models*

reliable results for a service oriented company located in Finland, if the use of energy is low compared to e.g. companies exerting manufacturing of products. High energy consumption could lead to misleading results with the U.S. data base due to the energy mix dissimilarities presented in Figure 13.

For additional comparison a calculation with only one sector from the Carnegie Mellon model was made. The most suitable sector describing the activities of Futurice was found to be Software Publisher. If the costs assumed to cause emissions were all allocated to this one category, the result was a total of 398 $tCO_2eq$. It is a severe underestimation of the emissions caused by the activities of the company. It cannot be seen as a reliable result for describing the impact of the company.

Even though the U.S. data base has a greater level of detail and is aimed for a broader use, it is assumed that country specific data is of greater importance for getting reliable absolute emissions. Therefore, the IO-results from the calculation made with ENVIMAT model were used for the hybrid-LCA.

*Table 15 Top 5 sectors for every category. Highest emission contributor to the left, decreasing impact to the right (Carnegie Mellon University Green Design Institute 2008a)*

| **Categories** | **Top 5 emission contributors** | | | | |
|---|---|---|---|---|---|
| Building premises | Power generation and supply | Waste management and remediation services | Nonresidential maintenance and repair | Oil and gas extraction | Petroleum refineries |
| Business Travel | Air transportation | State and local government passenger transit | Power generation and supply | Rail transportation | Oil and gas extraction |
| Activities within company | Power generation and supply | Cattle ranching and farming | Oil and gas extraction | Grain farming | Food services and drinking places |
| Office equipment and supplies | Power generation and supply | Waste management and remediation services | Truck transportation | Oil and gas extraction | Paperboard Mills |
| Purchased services | Power generation and supply | Couriers and messengers | Telecommunications | Oil and gas extraction | Air transportation |

## 7.5 Possible improvements

Areas of opportunity and suggested possible improvements are presented in this chapter. Based on the personnel questionnaire and the conduction of the carbon footprint possible improvements to decrease Futurice's environmental impact where identified. The suggested improvements are divided into improvements that would require financial investments and improvements more related to the behaviour and experience of the employees.

The improvements are inspired by Koivisto (2008) and Shrake et al. (2013). The carbon footprint revealed the categories where it would be most effective to decrease the emissions. Business travel has the greatest carbon intensity and already a small decrease would have significant environmental benefits. The willingness to use teleconferencing and lessen business travel was examined through the personnel questionnaire. It also gave an idea of what kind of issues the employees found regarding teleconferencing and what kind of improvements that could be made. To get both big economic and environmental benefits it would be lucrative to focus on improving the building premises. The personnel questionnaire touches this subject regarding office equipment energy usage and recycling. Based on the comments and answers regarding recycling it was found that improvements could be made regarding this subject. Commuting does not have a very big share of Futurice's carbon footprint, but the personnel questionnaire revealed that employees hoped for better facilities for bikers, therefore it is included. Services, equipment and supplies all cause notable emissions. They are however determined with the help of the IO-model prone to aggregation errors of purchased goods and services. That is why detailed suggestions about where to make improvements in these categories cannot be given.

*Table 16 Suggestion for possible improvements to decrease the environmental impact of Futurice*

| Suggestions of possible improvements | Building premises | Commuting | Business travel | Other |
|---|---|---|---|---|
| **Financial measures** | Green energy | Improvements for bikers | Follow-up on travelling | Choose responsible service, equipment and supply providers |
| | Recycling | | Improve tele- and video communication possibilities | |
| | Energy usage | | Flight $CO_2$ compensation | |
| **Behavioural change** | Education about recycling | Encouraging biking | Training in tele- and video communication | Raising awareness among stakeholders |
| | | | Consider when necessary to travel | |

To succeed in making progress, a plan on how and when to make the chosen improvements should be made and followed up regularly. Measuring the progress will help to see if the goals are actually achieved or if the strategy should be revised.

Table 16 presents the suggest improvements. The proposed improvements are all further discussed in chapter 8.3.

## 7.6 Data quality and sensitivity analysis

In this study data was received from different sources and therefore a quality analysis was performed with a data quality framework presented in the next chapter. The quality analysis will help to understand and interpret the reliability of the sources and results. A sensitivity analysis is made to show how variations in the input data will affect the output of the hybrid-LCA. The input variables to be tested are related to business travel and energy. These variables are chosen because of the level of uncertainty linked to them and business travel additionally represents the biggest part of the total emissions of the case company.

### 7.6.1 Data quality assessment

The data quality assessment was performed using a six-dimensional estimation framework, presented in the Nordic Guidelines on Life-Cycle Assessment (Lindfors et al. 1995, p. 67). The assessment framework has been suggested to be used in LCAs by Lindfors et al. (1995) and has earlier been used by, inter alia, Junnila (2004, 2006a, 2006b, 2006c, 2009) and Hellsten (2012). The framework consists of six quality categories which should be quantified on a scale from 1-5 (5 being the weakest score) for every data source. The framework is presented in more detail in Table 17. The get the highest score (1), continuously measured verified data over a suitable time period is required. In addition, the data should not be older than 3 years and the measurements should include an adequate sample size from the area of study. The lowest score (5) means that the representativeness, age of data and area of study

*Table 17 Data quality estimation framework, applied from the Nordic Guidelines on Life-Cycle Assessment (Lindfors et al. 1995)*

| Scale | Acquisition method | Independence of data supplier | Representativeness of sample | Data age | Geographical correlation | Technological correlation |
|---|---|---|---|---|---|---|
| 1 | Measured data | Verified information from public authority or other independent source | Data from continuous measurements over an adequate period at a sufficient sample of enterprises to even out normal fluctuations | Recent (maximum 3 years) | Data from area of the study | Data from enterprise under study |
| 2 | Calculated data based on measurement | Verified information from enterprise with interest in the study | Sample data or data from continuous measurements at a smaller number of enterprises but over an adequate period | Less than 5 years | Average data from larger area in which the area of the study is included | Data on same processes/ materials but from different enterprises |
| 3 | Calculated data partly based on assumptions | Independent source but based on non-verified information from industry | Data from shorter period but from continuous measurements at a sufficient sample of enterprises | Less than 10 years | Data from the area with similar production conditions | Data on same processes/ materials but from different technology |
| 4 | Qualified estimate (by industrial expert) | Non-verified information from industry | Sample data from shorter periods but from a sufficient sample of enterprises | Less than 20 years | Data from the area with slightly similar production conditions | Data on resembling processes/ materials and similar technology |
| 5 | Non-qualified estimate | Non-verified information from enterprise with interest in the strudy | Representativeness unknown or single or sample data from one enterprise from a shorter period | Age unknown or more than 20 years | Data from unknown area or area with very different production conditions | Data on resembling processes/ materials but different technology |

are unknown, which means that the estimates are non-qualified and non-verified. The target for the quality of the data for this study was to score between 2 and 3 and hence reach a level of satisfactory (level 3) data. The quality assessment is presented in Table 18.

As can be seen from Table 18 an overall score between 2 and 3 was reached for the input data of all categories. The overall score of cost data from the accounting records and the commuting data are still within the targeted quality level, even if they are a somewhat higher. The representativeness for the sample is low in all categories as this case study only involves one company. The independence of data suppliers for commuting is also low as the data originates from the personnel questionnaire and is not verified by anyone.

The quality of the secondary output data (emissions unit factors) is not as good as the input data (Table 18) and is unfortunately not quite reaching an overall score between 2 and 3. The representativeness of the samples is unknown, which is lowering the score. The technology, processes and material in the output data is resembling the company but cannot certainly be said to be the same and additionally the data cannot with certainty be said to only be based on measured data, leading to a lower score. The age of the data varies, and all data is from Finland. Hence the score 2 in geographical correlation and varying scores for data age.

*Table 18 Quality assessment of the data collected for this study*

| | Type of data | Acquisition method | Independence of data supplier | Representativeness of sample | Data age | Geographical correlation | Technological correlation | Score |
|---|---|---|---|---|---|---|---|---|
| Gathered input data | IO-data | 3 | 2 | 5 | 1 | 1 | 1 | ***2,2*** |
| | Energy consumption (District heating and electricity) | 2 | 1 | 5 | 1 | 2 | 2 | ***2,2*** |
| | Water consumption | 2 | 1 | 5 | 1 | 2 | 2 | ***2,2*** |
| | Waste consumption | 2 | 1 | 5 | 1 | 2 | 2 | ***2,2*** |
| | Commuting | 3 | 5 | 5 | 1 | 2 | 1 | ***2,8*** |
| Output data | IO-data | 3 | 3 | 5 | 4 | 2 | 4 | ***3,5*** |
| | Energy (DH and electricity) | 3 | 3 | 5 | 3 | 2 | 4 | ***3,3*** |
| | Water | 3 | 4 | 5 | 3 | 2 | 4 | ***3,5*** |
| | Waste | 3 | 3 | 5 | 1 | 2 | 4 | ***3,0*** |
| | Commuting | 3 | 3 | 5 | 3 | 2 | 4 | ***3,3*** |

### 7.6.2 Sensitivity analysis

A sensitivity analysis is performed for energy and business travel. The energy sensitivity analysis examines the impact of changes in energy usage and the impact of different emission unit factors. The sensitivity analysis for business travel studies the impact of different divisions between transportation modes and the impact of changes in the amount of business travel.

#### *7.6.2.1 Energy*

Even though energy usage is not the biggest emissions contributor in this case, it has been found to have a great impact in previous studies. (Junnila 2004; 2006a; 2006b; 2006c; 2009; Shrake et al. 2013). A sensitivity analysis regarding energy consumption and unit emissions was made to understand the impact of changes in energy consumption and unit emissions.

Table 19 shows that decreasing the energy consumption does not have a very significant impact on the total emissions. The impact is still not negligible and it can also have financial benefits. Decreasing the electricity consumption with 75 % would decrease the emission by 3 %, vice versa a 75 % increase in the electricity consumption would increase the emissions by 3 %. The same analysis was made for heating consumption. A 75 % decrease in heating would decrease the total emissions by 2 % and vice versa. The energy consumption per square meter in the building is bit above average, but normal for a building of its age. Lowering the energy consumption would mostly require actions from the building managers side regarding heating and ventilation.

The energy unit emissions were also analysed. The European Union has in 2010 published a guidebook called "How to develop a sustainable energy action plan (SEAP)". In the second part of the guidebook "Baseline emissions inventory" emissions factors for consumed energy are presented both for standard and LCA approaches. The standard emission factor is close to the used emission factor in this study, the LCA emissions factor is though much higher and the impact using the LCA factor instead is analysed. (Covenant of Mayors 2010.) Moreover, Helsinki has a goal to be carbon neutral in 2050, which energy wise means aiming for renewable energy instead of fossil fuels (Helsingin Kaupunki 2015). The emission from renewable energy production is however debatable and the numbers vary a lot. Reported emissions for wind energy vary between approximately 5 and 55 $gCO_2eq./kWh$ and for hydro between approximately 1 and 34 $gCO_2eq./kWh$ (Weisser 2007; Raadal et al. 2011). In Finland, a big part of the renewable energy comes from hydro and wind but mostly from wood fuels (Luke 2016). Väisänen (2014, p. 93) uses an emissions value of 12 $gCO_2eq./kWh$ for wood fuels. In the sensitivity analysis, the value of 12 $gCO_2eq./kWh$ will be used. The higher emissions factor alternative used for heating is 400 gCO2eq./kWh and represent separate (opposite of CHP) district heating production (Hippinen, I. and Suomi, U. 2012).

*Table 19 Sensitivity analysis of energy consumption and unit emissions.*

| | | | | |
|---|---|---|---|---|
| **Sensitivity analysis electricity** | **Electricity consumption** | Consumption [kWh] | kgCO2 | Change in total emissions |
| | *Electricity rconsumption eference value* | *140482* | *30625* | |
| | 25 % decrease in electricity consumption | 105361 | 22969 | -0,6 % |
| | 50 % decrease in electricity consumption | 70241 | 15312 | -1,1 % |
| | 75 % decrease in electricity consumption | 35120 | 7656 | -1,7 % |
| | **Electricity unit emissions** | gCO2eq./kWh | kgCO2 | Change in total emissions |
| | *Used unit emission value* | *218* | *30625* | |
| | European Union LCA average* | 418 | 58721 | 2,1 % |
| | Wood** | 12 | 1686 | -2,1 % |
| **Sensitivity analysis heating** | **Heating consumption** | Consumption [kWh] | kgCO2 | Change in total emissions |
| | *Heating consumption eference value* | *197590* | *46038* | |
| | 25 % decrease in heating consumption | 148192 | 34529 | -0,8 % |
| | 50 % decrease in heating consumption | 98795 | 23019 | -1,7 % |
| | 75 % decrease in heating consumption | 49397 | 11510 | -2,5 % |
| | **Heating unit emissions** | gCO2eq./kWh | kgCO2 | Change in total emissions |
| | *Used unit emission value* | *233* | *46104* | |
| | Separate district heating production*** | 400 | 79036 | 2,4 % |
| | Wood** | 12 | 2371 | -3,2 % |

* European Union, 2010

** Väisänen, 2014

*** Motiva, 2012

From Table 19 it can be seen that the higher emission factor for electricity would increase the total emissions of Futurice with roughly 2,1 %, and that use of only renewable energy would decrease the total emissions with the same amount. Even though the impact on total emissions is marginal, the alternative emission factors either almost double, + 92 %, the emissions from electricity or cuts them by 94 %. The same goes for heating, the impact on total emissions is somewhat bigger but still marginal. The higher emission factor increases the total emissions by 2,4 % and the lower factor decreases the total emissions by 3,2 %.

Again, the impact on heating emissions is substantial, an increase of over 70 % or a decrease of 95 %.

### *7.6.2.2 Business travel*

Business travel is found to be the biggest contributor to Futurice's emissions. The amount of transport by flight, train or bus is though estimated based on the accounting records since no further division of travel tickets is made in the company's bookkeeping. Car and taxi use is separated. A sensitivity analysis of the share of different transportation modes is in place to see the impact of different assumptions regarding the distribution between travelling modes. Table 20 shows that moderate adjustments in the distribution between transportation modes have marginal effect on the total emissions. As the ticket price for flights normally is higher than for bus or train it is seen improbable that the share of flight tickets would go below 30 % of the costs of all tickets.

The other sensitivity analysis looks at the business travel category as a whole. The assumed changes in this category are much smaller than in the sensitivity analysis for energy. This is due to the fact that the company values their meetings in person with customers and other employees and are not ready to decrease their business travel extensively. The sensitivity analysis shows that even an as little change as 5 % has similar impacts as a 50 % change in electricity or heating consumption. Decreasing business travel by 10 % would decrease the overall emissions by 2,9 % and a 20 % decrease would decrease the emissions by 5,8 %. Already a small decrease in business travel has a rather big impact on the total emissions of the company. The emissions from business travel are, however, assessed based on the costs of the tickets. This means that also cheaper tickets would affect the results in a positive way and vice versa. Hence, the analysis also shows the sensitivity of changes in travel costs. It is important to recognise that the IO-model is based on average emission per currency and does not take into account specific conditions and situations.

Changing the assumed shares of transportation modes does not indicate a very big change in total emissions. Looking at Figure 15 e.g. replacing flights with train would decrease the emissions by a ratio of 1:5 and with bus by a ratio of 1:4. Based on Figure 16 changing to train would decrease the emissions even by the ratio 1:20. This would indicate a much bigger change in the total emissions if the ratio of the transportation modes would change. E.g. a 30 % decrease in flights and increase in train would indicate a change of a magnitude closer to 8 % (assuming the 1:5 ratio). The low sensitivity shown by the analysis (Table 20) is caused by the fact that the emissions from business travel has been estimated using the IO-LCA model, which falsifies the actual effect of changing transportation modes.

*Table 20 Sensitivity analysis of business travel.*

| | **Transportation mode** | Flight | Train | Bus | Change in total emissions |
|---|---|---|---|---|---|
| **Sensitivity analysis business travel** | *Reference* | *60 %* | *30 %* | *10 %* | |
| | Alternative 1 | 50 % | 35 % | 15 % | -1,0 % |
| | Alternative 2 | 40 % | 40 % | 20 % | -1,9 % |
| | Alternative 3 | 30 % | 45 % | 25 % | -2,9 % |
| | **Whole category** | | Emissions (kgCO2eq) | | Change in total emissions |
| | *Reference* | | 395981 | | |
| | 5 % decrease in business travel | | 376182 | | -1,4 % |
| | 10 % decrease in business travel | | 356383 | | -2,9 % |
| | 20 % decrease in business travel | | 316785 | | -5,8 % |

# 8 Discussion

The goal of this research was to find the relevant components for determining the carbon footprint of a service oriented company and find the components with the biggest emissions. Suggestion for how to reduce the carbon footprint was also a part of the goal. The study was performed as a literature research and as a case study defining the carbon footprint of a case company. The results of the hybrid-LCA in this study indicated that of the company's activities business travel cause the most emissions. Purchased services, office supplies and office equipment contribute notably to the emissions. Building premises and commuting were found to cause less significant emissions. The results of the hybrid-LCA is very close to both of the performed LCAs using only IO-LCA data. It is due to lack of process data in this study, where only commuting, energy, water and waste could be modelled with PRO-LCA data.

Earlier studies have found the carbon intensity per employee to be vary between 3,1 and 21,1 $tCO_2$eq./employee. The average impact is 7,4 $tCO_2$eq./employee and the median is 5,9. (Junnila 2004, 2006a, 2006b, 2006c, 2009; Shrake et al. 2013.) The results of this study fall within these frames, with the outcome 4,9 $tCO_2$eq./employee. It is somewhat lower than the average and median from the previous studies. The efficient office space usage and the great location of the premises are affecting the results in a decreasing manner. The used unit emission factors may also derive some difference; the used emission factors in this study might be lower than in some of the previous compared studies. The varying boundary definitions might also cause differences in the results. The calculation principles of the previous studies are not fully revealed, making it more difficult to define the differences.

In previous studies office equipment and office supplies where separated into two groups. The office supplies accounted for only 0-6 % of the emissions and hence in this study it was not seen necessary to separate these categories and they are combined to the group office equipment and supplies. Additionally, one group was added, activities within the company. Based on the accounting records and the characteristics of the company this was seen as the most suitable division for determining the carbon footprint of the case company. Differences in boundaries as well as in grouping of data and matching of accounting data with IO-sectors has an impact on the distribution of the emissions. In addition, the book keeping principles of costs also vary among companies. The same costs might be booked under different names in different companies. This makes the comparison category wise more uncertain.

The category causing most of Futurice's emissions was business travel. It stands for 29 % of the company's emissions. In the earlier studies, where business travel and commuting were separated, business travel constituted 1-38 % of the emissions (Junnila 2004; 2006a; 2006c). In these studies, solely the actual travel from one place to another (measured in emissions per distance) is considered, whereas in this study everything related to business travel is included (accommodation, parking costs and other travel costs). Business travel was only in one case of the previous studies found to cause the biggest emissions (40 %), however, in this case commuting was included (Shrake et al. 2013). In most cases office premises had the biggest share of the emissions. (Junnila 2004, 2006a, 2006b, 2006c, 2009; Shrake et al. 2013.), which is not in line with this study where the office premises cause only 15 % of the total emissions. The combined impact from office equipment and supplies varied between 0 % to 18 % and for purchased services (where accounted for) between 3-48% in previous studies. In this study, the results the impact was 18 %respectively 19 %. Though, as already noted the difference in boundaries impact the distribution of the emissions.

The results and comparison of the hybrid-LCA to previous studies will be further discussed in the following chapters.

## 8.1 Evaluation of results

### 8.1.1 Business travel and commuting

Business travel is the most emitting category of the company studied, accounting for 29 % of the emissions with a total of 396 $tCO_2eq$. This equals 1,42 $tCO_2eq$./employee. Based on the characteristics of the company it was assumed that business travel would have a big impact. Flights stand for 44% of the emissions. This is in line with earlier studies where flights also were found to stand for most of the business travel emissions (Junnila 2004, 2006b, 2006c). Earlier studies, where commuting is not included in business travel, have reached results ranging from 0,1 to 6,7 $tCO_2eq$./employee, representing 1-38 % of the emissions. The average is 1,4 and the median is 0,7 $tCO_2eq$./employee. The emissions per employee for Futurice are close to the average, though double the median. Even though business travel causes most of the impacts it is not followed up by the company. Due to lack of travel logs the emissions from business travelling was determined with data from the accounting records using the ENVIMAT IO-LCA model. Further it was not possible to specify which travel mode had been used (except taxi and car which are accounted for separately) and assumption had to be made regarding the division of costs between modes of transportation (train, flight, bus). The previous studies have determined the environmental impact through emissions per kilometre, which in this study was not possible. In this study accommodation, travel arrangement and parking were also included in this category, which is not the case in previous studies. In Junnila (2006c, 2009) hotel accommodation was included in purchased services. Accounting for activities purely related to travelling distances, the impact would be 22 % and 1,1 $tCO_2eq$./employee. If the travelling service activities are instead included in purchased services, that category would be the most emitting category. Business travel would still be the second biggest.

Business travel is very dependent on the activities of the company. Those travelling much by air will have bigger emissions because of the GHG intensity of air travelling. From the previous studies high emissions were explained e.g. by main customers located abroad or by significant amount of driving in demanding conditions requiring robust cars with higher emissions. Futurice has offices around Europe and also travel to customers in Finland leading to a significant amount of business travel.

### 8.1.2 Office premises

The office space contributes with 0,76 $tCO_2eq$./employee making it a total of 210 $tCO_2eq$. which stands for 15 % of the emissions. Previous studies report impacts of 25 – 58 % coming from office spaces with intensities of 1,4-7 $tCO_2eq$./employee. Office space was the major emission contributor in 15 out of 17 cases in the previous studies.

The reported office space per employee in the earlier studies is 21-33 $m^2$ (Table 6) (Junnila 2004, 2006c, 2009). It is also the category representing the biggest impact in most of the cases. Junnila (2004, 2006a) and Shrake et al. (2013) concludes that companies interested in improving their environmental performance should focus on building use and especially on energy efficiency. In this case the office space efficiency is much higher as the company has roughly 5,25 $m^2$ per employee. Employees are often at the customers' offices and thus there is no need for a specific working station for everyone at Futurice's office. The size of the office directly affects the energy usage, amount of waste, water usage etc. evidently decreasing the emissions in this category. In this study, all facilities related activities are included in this category whereas in Junnila (2006b, 2006c, 2009) repair and maintenance is included in purchased services. Construction is not considered in this study as the company is renting their spaces. Maintenance, cleaning and security are included in the category in this study. Moving these activities to purchased services instead would make the impact from office premises even smaller, decreasing it to around 6 % or 0,3 $tCO_2eq$./employee.

Energy consumption stands for most of the emissions (39 %) from office premises. It constitutes of electricity, district heating and district cooling. Electricity was found to cause 0,11 $tCO_2eq$./employee compared to 0,9-6,6 in previous studies. Emissions from heating were 0,17 $tCO_2eq$./employee in this study and 0-1,4 $tCO_2eq$./employee in previous studies. (Junnila 2004, 2006b, 2006c.) District cooling had only a minor influence, counting for 0,02 $tCO_2eq$./employee. Though it is not a major emission contributor there may be room for improvements in the temperature control in the building. The use of district cooling was relatively constant over the year even though cooling during cold month should be clearly lower, indicating possible cross cooling and heating of spaces in the building.

Waste management emissions were based on the waste amounts collected on building level. The actual waste amounts for the case company cannot be analysed furthered as waste was not followed on company level. From the personnel questionnaire, it was though seen that recycling and waste collection was not very straight forward for the employees and this could need some improvements.

Cleaning stands for 22 % of the premises emissions and has an as big impact as heating; 0,17 $tCO_2eq$./employee. Maintenance stands for 33 % equalling 0,25 $tCO_2eq$./employee and guarding and security for 4 % or 0,03 $tCO_2eq$./employee. These impacts are calculated with the ENVIMAT IO-data. Especially maintenance and cleaning have significant impacts regarding the emissions of the premises.

There space usage is very efficient in the case company and it is the main reason leading to the small impact of this category. The impact is however not negligible. Improvements in this category should according to his study focus on electricity usage, maintenance and cleaning.

### 8.1.3 Office equipment and supplies

Office equipment and supplies where combined into one category in this study. In the previous studies they were studied as separate categories. This was, however, not seen necessary for this company, due to the small impact shown by office supplies in earlier studies and based on categorisation in the accounting records. Office equipment and supplies includes computers, paper, newspapers, presents, phones, meals etc. In previous studies (Junnila 2006c, 2009) meals and rental of computers is included in purchased services. Here it was seen that also the rented computers are part of the company's equipment and hence placed in this category. Meals for personnel were thought of as mainly a supply of physical food instead of mainly being a service and therefore meals are included in this category, instead of purchased services, in this study.

In previous studies office supplies were found to cause 0-0,6 $tCO_2eq$./employee and office equipment 0,1-1,3 $tCO_2eq$./employee. Combined it makes 0,1-1,9 $tCO_2eq$./employee with a median of 0,5 and an average of 0,7 $tCO_2eq$./employee. In this study, the emissions per employee was found to be 0,9 $tCO_2eq$. This is somewhat bigger than the median and average, yet in line with previous studies. The share of office supplies and equipment was in this study 18 %. In previous studies it was found to be 2-18%, where the median and average around 10 %, thus showing a somewhat greater significance in this study than on average. The components causing most emissions are IT equipment and coffee supplies. A more similar boundary definition as the previous studies would however lead to smaller emissions in this category and greater emissions in purchased services. The emissions in this category would still be in line with the previous studies and the impact share would land on the average, being 10 %.

### 8.1.4 Activities within the company

This category is not found in the previous studies. Studying the accounting records of Futurice and considering the characteristics of the company the solution to add a new category arose. A category representing activities happening within the company was seen as an adequate solution. Many of these activities have in previous studies been included in the purchased services category. In this study, the aim was to keep the purchased services category as a category representing services purely paid for, assumed to not require any activity from the company's side. E.g. marketing and education e.g. are included in the activities within the company category, since these are assumed to require actions from the company's side. This division was also made to be able to show the company the impact of activities they are a part of compared to purely bought services. This may help to see where the focus should be in order to decrease the emissions. Either make changes in the internal activities or try to find service providers with low environmental impact alternatively try to influence the existing service providers to decrease their emissions.

The calculated impact of this category is 0,71 $tCO_2eq.$/employee and stands for 14 % of the total emissions. This shows that internal decision about the execution of events, parties, marketing and training of personnel does make a difference. The activities causing most emissions are internal meetings, staff parties, marketing and recruiting.

### 8.1.5 Purchased services

Purchased services is a category often overlooked and assumed not to cause any emissions (Shrake et al. 2013). Both this and previous studies however show that this category can cause significant emissions. It makes a difference especially in service oriented companies that seldom have any direct emissions. In the previous studies, where purchased services where included and assumed to have an impact, the emissions were found to be 0,1-10,2 $tCO_2eq.$/employee. The median was 1,0 and the average emissions were 2,0 $tCO_2eq.$/employee. The variation is very big and can partly be explained by the difference in the used amount of purchased services in the companies. (Junnila 2006b; 2006c; 2009; Shrake et al. 2013.) Both previous studies as well as this study show that it cannot automatically be said that a company's purchased services will have a significant impact on the company's emissions, vice versa it cannot be assumed not have an impact at all.

In this study, as mentioned earlier, purchased services was decided to be kept as a category with purely services that do not require the company itself to act. By all means, it can be discussed weather this restriction was fully followed as the division of bookkeeping records into categories is subjective. Activities can be interpreted differently, but that was, however, the aim and the idea behind the boundary definition. The emissions from this category was in this study found to be 0,92 $tCO_2eq.$/employee and represented the second biggest category emission wise (though very close to the other categories in the middle). The biggest emissions causing activities are software upgrade and maintenance, accounting, hosting and telephone services

Again, as noted before, many activities that in this study are allocated in other categories have in previous studies been included in this category. With a boundary definition closer to the previous studies this would with no doubt have been the category with the greatest impact. This emphasises the fact that not only physical things bought to enable a service company's business contributes to its carbon footprint. The services purchased from other service oriented companies can even stand for most of the company's emissions. As purchased services are also found in the other categories it emphasizes the importance of choosing responsible and reliable service providers.

## 8.2 Relationship between emissions and money

In a competitive world businesses stand in front of optimisation challenges where both economic and environmental variables are a part of the decision-making process. It is often the cost structures and budgets that drive the operational management in the end. (Junnila 2009, p. 423.) Studying the relationship between costs and emissions can help companies prioritise where to cut costs while at the same time maximising the reduction of their environmental impact. Understanding the relationship between costs and environmental impact may also motivate employees to behave more environmentally responsibly (Koivisto 2008, p. 124).

One activity where both the environmental impact and the carbon intensity (kg$CO_2$eq./€) are high is business travel. It means that even a small reduction cost wise would have significant effect on the environmental impacts. All other categories show similar relationships between the environmental impact and carbon intensity. The relationships between carbon intensity and environmental impact are illustrated in Figure 33. In these categories a reduction in costs would have a moderate impact on the emissions. According to this it would be most efficient to decrease business travel as a small reduction in travel would have a big environmental impact decreasing the emissions.

Figure 36 shows the relationship between costs and emissions in a slightly different way, combing both carbon efficiency (€/kg$CO_2$eq.) and intensity (kg$CO_2$eq./€) into one matrix. Categories where both the carbon intensity and the efficiency are high is building premises. Focusing on intensifying this category would have benefits both cost and emission wise. Business travel has the highest environmental impact and carbon intensity. The costs are, however, not as significant as for other categories and business travel has the lowest carbon efficiency. The office supplies and equipment category has a similar division between carbon efficiency and intensity as business travel. This means that if the emissions from business travel or office equipment and supplies were decreased as much as in building premises it would not have an as big economic benefit. On the other hand, business travel has the highest carbon intensity so the same reduction in cost in both categories would have a bigger impact on the emissions if costs were reduced in business travel.

Due to the great location of the premises commuting has the lowest environmental impact of all categories. Moreover, it is assumed to not have any financial impact on the company. The financial advantages of reductions within the categories activities within the company and purchased services are significant. The impact on $CO_2$eq. emissions from cost reductions in these categories will, though, be less than for reductions in building premises, business travel and office equipment and supplies.

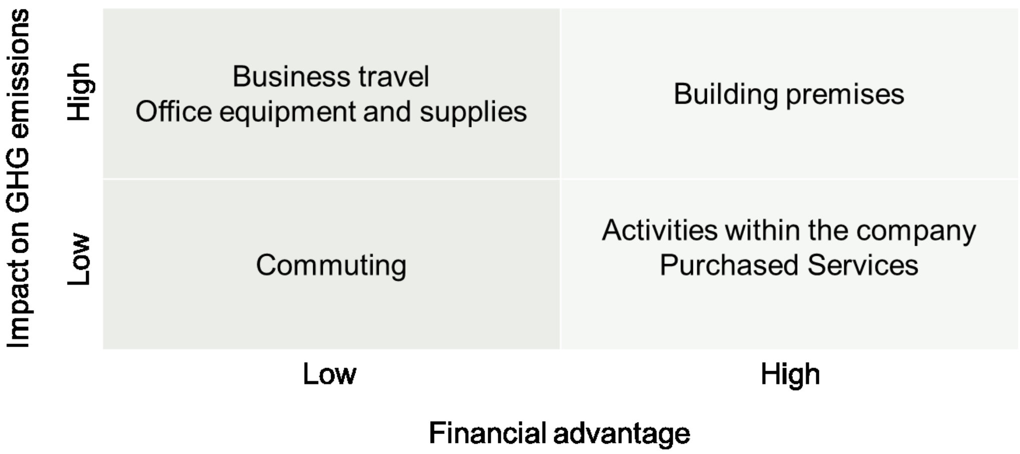


*Figure 36 Matrix of the financial advantage and impact on emissions in the case of reductions in the different categories*

One should however not stair blindly on the matrix (Figure 36). The figures are all subject to uncertainty due to the margin of error in the allocation of costs. Bookkeeping habits affect the results as well as the division into the six main categories. Process data for the building premises could not be matched to costs in a certainly enough for it to be possible to study the relationship between emissions and costs in more detail.

Although the indicators (cost and emissions) presented in Figure 36 are suggestive, they clearly demonstrate that a direct correlation between emissions and cost does not exist. Focusing on financial targets would not direct the reductions to business travel, the most emitting category. Setting targets and doing measurements only based on costs will not reduce the emissions efficiently.

A direct comparison with previous studies is difficult due to differences in boundaries. Hence, the following comparison is prone to uncertainty. Junnila (2009) found that after wages (assumed to not cause any environmental impact), purchased services was the biggest category, with an environmental impact, on which the companies spent money on. This is in line with this study. In Junnila's study second most money was spent on office premises. Thereafter office equipment, business travel and last office supplies. In this study, second most money was spent on activities within the company followed by office equipment and services, building premises and last business travel. The cost division is, however, very equal among the categories in this study.

Regarding the impact intensity on climate change (kg$CO_2$eq./€) Junnila (2009) found that office premises had the greatest impact intensity varying from 0,42 to 1,21, followed by business travel 0,36-0,91. Equipment (0,08-0,28) and supplies (0,06-0,32) had similar intensities, leaving services as the least emission intense category (0,06-0,35). In this study business travel had the greatest intensity of 0,78, followed by office equipment and supplies (0,35) and building premises (0,32). The lowest intensities are represented by activities within the company (0,26) closely followed by purchased services (0,24). The results from this study are somewhat in line with the previous study.

## 8.3 Possible improvements in the case company

Even though the results show that, compared to earlier studies, the carbon footprint of Futurice is in the lower end, improvements can always be made. The fact that they are good compared to others does not necessary mean it is good enough environmental wise. Suggested improvements are divided into improvements that would require economic measures and improvements that are relying more on changes in the behaviour of employees. A summary of the proposed possible improvements has been shown in Table 16.

### 8.3.1 Improvements requiring financial measures

The building premises are already very efficiently used which means that there is not much to be improved in this category. Some improvements could yet be made. Changing the energy contract to green energy is an easy and not very costly way to lower the emissions from purchased energy. Recycling was not very upfront for all employees and improvements could easily be made. Clearer signing on where and how to recycle as well as increased knowledge through training and education would make the recycling effortless and convenient for all employees. Additional recycling bins (especially paper and bio) would also improve the recycling. Even though waste isn't a major emission contributor at Futurice, creating the perquisites for proper recycling is a way of showcasing the values of the company. It can also create a feeling of being a part of the movement for employees and learning how to recycle a work may also improve recycling in the homes of the employees. It should also be ensured that e-waste is handled properly. Energy usage is already quite efficient at the office. According to the personnel survey people turn off their computers when not used and the majority of computers are laptops and not desk computers. The biggest improvements possibilities are linked to the building HVAC (Heating, ventilation and air conditioning) and lighting. Lighting was not studied more in detail and there might be some opportunities of efficiency improvement here. The building is old and therefore the energy use per square meter is a bit above the average. Efficiency improvements in HVAC would need to be undertaken by the building manager e.g. making sure that the HVAC systems are working correctly.

Commuting is not either causing much of Futurice's emissions due to good location. Facility improvements for bikers was, however, desired based on the personnel survey and would most likely increase the degree of biking. Everyone is not aware of the bike storage and changing facilities in the building, a simple tour in the building would solve this problem. Still, better changing and shower facilities as well as a bike storage were still hoped for. If the building managers is not willing to improve this Futurice could consider doing it in their own spaces. Further lockers to store clothes, drying cabinet, first aid biking gears and tools, and office bike(s) are ideas for improved circumstances for bikers. To encourage people to come by bike it has to be easy.

Business travel causes most of Futurice's emissions. One possibility to lower Futurice's environmental impact, that would need economic input, are flight $CO_2$ compensations. It is an easy way to green the company's travelling. It is however not targeting the core issue, the amount of travelling. Another improvement is the follow up of travelling which could be done in more detail (e.g. through requiring more detailed information when employees apply for travel compensation or through a separate app used by the employees). This would allow analysing the actual travelling and it would be easier to target and recognise possible unnecessary travelling. In order to encourage people to use less travelling and more video- and teleconferencing the right conditions must exist.

The level of detail in the carbon footprint calculation for purchased services, activities within the company and office equipment and supplies is not very high. The calculations are based on monetary values and average emissions for Finnish businesses. Hence to get the actual emissions it would require very detailed research about the providers used by Futurice either by going through old invoices one by one or by gathering the invoices under a monitoring period. However, Futurice can be conscious about the fact that purchased services, equipment and supplies cause a very significant part of their emissions. It is therefore important to carefully choose sustainable and environmental friendly providers.

### 8.3.2 Improvements requiring behavioural changes

Education and training can change employees' behaviour in a more environmental responsible direction (Koivisto 2008). For Futurice education regarding recycling and telecommunication could improve the experience and ease of the employees.

To help employees recycle correctly knowledge and guidance about how to recycle different kinds of waste will be supporting. Also, stickers or other kinds of markings with symbols and information can help people when they are hesitating. Further, it is crucial that everyone knows where the recycling bins are and what to do when they get full.

Tele- and videoconferencing divided the opinions among the employees. A significant share does not use it very often and there were many comments about technical issues and feeling uncomfortable in the personnel questionnaire. Futurice is already working on improving the technical equipment but that will not solve the entire problem. If people do not know how to use the equipment or feel uncomfortable using it, they won't voluntarily increase their usage. Organising training session for employees about how to use the equipment properly could help coming over the first obstacle. Having a tele- or videoconference meeting is not the same as having a face to face meeting. Advice, guidelines, practice sessions on how to act and behave in these, maybe uncomfortable and unfamiliar, situations can then help. The more one uses the technology the more comfortable one will get.

Several comments were expressing concerns about replacing personal meetings with tele- and videoconferencing. This is however not the aim. An example from Albertao (2012, p. 73) may help explain the situation. Albertao claims that some improvements may be beneficial from an environmental point of view but negative to the overall sustainability. He uses teleconferencing as an example: less physical meetings can impact the environment positively but affect team cohesiveness and motivation in a negative way, which in the worst case threat the sustainability of a whole project. Therefore, Albertao suggests that measurements should not only focus on answering the question "How much $CO_2$ does my team emit", it should also start discussions like 'Why not take the bike to a client instead of going by bus?' or 'Why not use teleconferencing instead of travelling this time?'.

Using teleconferencing to a greater extent does not mean completely replacing face-to-face meetings, only revising when it is really needed. Encounters in person with customers and colleagues in different locations is an important part of the work and meeting people in real life is not the same as virtual meetings. However, efforts can be made to think when it is necessary to travel, especially longer distances that require flying. Already meeting once in person makes it easier to continue over video-and telecommunication. Travel is also both money and time consuming. Further it can be though about how many that have to travel, is it perhaps enough if one person goes? In addition to regular meetings, Futurice has organised events for the whole company. It could be thought about if this could be done e.g. near the location of one of the offices, this way a whole office of people does not have to travel that far having a significant impact on the GHG emissions.

Coming by car and bus can be equally emitting depending on the characteristics of the car. Hence to improve commuting encouraging the use of rail transport and biking will make a difference. Improving the circumstances for bikers can already motivate people to come more by bike. However, Futurice can also encourage people to use bikes more e.g. by joining campaigns, hand out rewards, showing biked kilometres on a screen or by using any other motivating carrot. Workshops about biking related topics may also work as an encouragement, e.g. basic repair skills, the correct biking positioning, health effects of biking etc. Biking has also health related benefits that can benefit the company in the long run. It has e.g. been found that people who bike to work are less stressed, that is good for the brain activity and that it strengthens the heart and the blood circulation (Tommola 2017). As many work at customers' offices it could be made a habit to ask about their storage and changing facilities for bikers. This way employees of Futurice could bike also to customers without having to ponder about the changing opportunities.

All the work that Futurice does to improve their environmental impact and decrease their carbon footprint should be informed to all stakeholders. Actively working towards a more environmental responsible business, being open about the process and actions taken and creating an encouraging atmosphere for environmental responsible behaviour will raise awareness among employees, customers and other stakeholder, not only about the environmental work itself but about environmental issues in general. Koivisto (2008) emphasised that the roles of the directors in a company are crucial. The culture of the company influences the commitment of employees towards environmental issues. Showing appreciation of employees' own environmental efforts can further engage employees in their environmental learning process.

## 8.4 Limitation of the study

All data is based on last year's measurements and purchases. Not following up the consumption for a year or having the possibility to trace back the book-keeping records to the actual invoices creates room for aggregation mistakes. Further uncertainty is created by the IO-databases aggregation to a limited number of sectors that should represent all possible activities. Hence, the calculations are based on sector averages not accounting for more, or less, environmentally friendly acquisitions. For more accurate results the accounting records should be traced back to the invoices. Alternatively, purchases should be tracked during a year, which though is a time-consuming process requiring thorough follow-up during a whole year or access to all invoices.

Business travel was based on monetary values only. Detailed information about travelling destinations or transportation modes was not available, leading to assumptions. Assumptions in turn weakens the reliability of the outcomes. Since the category with the highest emission contribution has been determined with relatively uncertain data, one has to be cautious when interpreting the overall results. However, using two independent IO-datasets provide some additional confidence on the key finding of business travel being the primary carbon footprint contributor within the case company. IO-data suffers from severe aggregation errors. One trip to Munich bought on sale may costs as much as a ticket to Stockholm bought in the last minute. These flights naturally does not have the same environmental impact even though the IO-model would imply it if the price is similar. More detailed information would require that the company follows up business travel more in detail.

Actual measured data could only be obtained for a few activities. Commuting habits were studied through a personnel questionnaire with an answering rate of 36 %. The carbon footprint was determined using the average commuting distances for the office that were based on the questionnaire. Further the share of different transportation modes used were also based on the questionnaire. This creates some level on uncertainty. If, e.g. most of the people who did not answer would come by car. Futurice, however, confirmed that the results from the questionnaire describe the actual situation. Data for energy, waste and water was measured on building level and allocated to the office according to the share of the whole building area, again creating room for uncertainty. Measurements on company level would be required for greater accuracy.

This study divided the emissions into six categories in a slightly different way that previous studies. A more similar division would have made the comparison easier and more accurate. However, LCAs are prone to many subjective choices and the lack of comprehensive guidelines makes the comparison of different studies uncompleted. The GHG protocol also states that it is not intend for comparison between companies, but for comparison within a company and its GHG emissions over time.

The study focused on the carbon footprint. Therefore, the emissions are presented only as $CO_2$ equivalents, which show the environmental impact on climate change, also known as global warming potential. All other environmental impacts, e.g. ozone depletion, acidification and smog among others, were excluded. Other impacts may show different weight values for the processes studied and hence for a more comprehensive environmental impact assessment, other environmental aspects should be considered as well.

## 8.5 Recommendations for further research

In order to explain the reasons behind the emissions of a service oriented company more thoroughly, further research is needed. Due to both lack in data collection from the case company and the general level of the IO-data this study was unable to explain the results in a very detailed manner. To fully be able to explain the reasons behind the emissions, follow-ups and measurements of the company's activities should be done prior or as a part of the study. Ideally, measurements and data collection would be planned and done during a follow-up period. The study found that follow-ups and measurements of activities are not necessary a natural part of a company's management, which can limit the study. The advantages of and need for data collection processes in service oriented companies would require more research.

As the used data was mostly based on the monetary values of the accounting records from the previous year and the emission data was based on the ENVIMAT model, the results are not accounting for specific choices of the case company. The case company may either purchase more, or less, environmentally friendly services, equipment and supplies than the average Finnish product and service providers. The ENVIMAT model has only 52 sectors representing emissions per euro for the purchaser. A more detailed model would allow for more detailed analysis of the results. Further a model of how to account for environmentally responsible choices already made within the company should be developed.

This study implies that the purchased services are of significant weight for a company with similar characteristics. It would require further research to understand he actual impacts from the purchased services. The data in this study did not allow a more detailed analysis of the purchased services. Further this study suggests that good location has a major impact on commuting habits. Additional factors influencing the commuting habits were not looked into and a deeper understanding could be achieved with more research.

The study adds to earlier research about the environmental impact of service oriented companies. It was, however, found that the differences in boundaries make comparison uncertain. Further research and guidelines on how to divide the activities of a company into categories would make the process more straight forward and less prone to objective choices of the author. Additionally, the numerous ways of conducting LCAs and carbon footprint calculations is an issue. There are no regulations on what has to and what can be left out from the assessment, which makes different assessments incomparable; this is an issue that should be addressed.

# 9 Conclusion

The purpose of this study was to find the relevant components for determining the carbon footprint of a service oriented company and the activities and variables that stand behind the major emissions. To assess the carbon footprint of the Finnish case company Futurice, an application of the hybrid life cycle assessment (LCA) was utilised. The emissions caused by the company's activities during a year were analysed and compared to results from earlier research. The activities were clustered into six main categories: business travel, building premises, office equipment and supplies, activities within the company, purchased services and commuting.

In most cases in earlier research building premises and travelling showed to cause the biggest emissions. This is suggesting that companies could focus on facility management and business travel variables to decrease their environmental impact. This study however shows that this may not always be the case. The office premises of Futurice are very efficiently used, moving the focus to other categories. Business travel has the biggest impact, followed by the other categories having similar impact shares, though with commuting being the category with the smallest impact. This indicates that all components are relevant or at least somewhat relevant for determining the carbon footprint of a company with similar characteristics. On a more general level it can be concluded that it cannot initially be assumed that some components are not relevant and can be left out, as it depends on the characteristics of the company which components that cause significant emissions and which not. However, for a similar company to the case company of this study, the most relevant components are related to business travel and purchased services. Focusing on these two categories can give a good start for the environmental work. More detailed components needed for determining the carbon footprint would be emissions unit data, as much process data from the company as the scope of the study allows and then comprehensive accounting records and IO-LCA data for the rest.

The aim was also to consider ways on how to decrease the emissions of the major emissions contributors. Suggestions for reducing the emissions business travel, the major emissions contributor, are to reduce the amount of travelling and increase the use of telecommunication. Thorough follow-up could help the company recognise unnecessary travelling. Buying flight carbon compensation is also a possibility, and could e.g. be used to green the absolutely necessary travelling. Other ideas of improvement to reduce the company's carbon footprint where organising education and training for the employees about recycling and telecommunication, increased number of recycling bins, green energy contract, improved facilities for bikers as well as different kinds of motivational carrots to get people to bike to work.

The relationship between costs and emissions were analysed to give guidelines on where it would be most efficient to decrease the emissions and where the reduction of emissions would as well create great financial value. Any direct correlation between the emission- and cost-intensity was not found. Business travel caused most of the emissions and had the highest carbon intensity per cost but purchased services stood for most of the costs. If costs are driving the environmental improvements, savings concerning business travel will have the biggest impact on emissions. The other categories had similar cost- and emission-intensities, where savings would have moderate impact on the emissions. Lowering emissions of purchased services, standing for most of the costs, would have high financial benefits. To get the most savings both financial and emissions wise reductions in office premises are recommended.

There are several uncertainty factors linked to the study and to LCA calculations in general. The fact that there are several LCA-tools and no generally acceptable emissions factors, forces the practitioners to make subjective choices and report accordingly. Further, also the boundary definitions, grouping into categories as well as matching IO-data with the monetary values are prone to cause uncertainty because of choices that have to be made by the practitioners. Companies may basically choose the level and scope of their carbon footprint freely. When consumers then compare two companies based on their emissions reporting they may not be aware of the differences that can lay behind the calculations. Carbon footprint calculation is already an accepted method by the public making it even more important and urgent to standardise the method. Moreover, the general values of the IO models make detailed analysis difficult. The models do not consider purchases that are worse or better than the average and may either give to optimistic or pessimistic results.

Even though regulations may not specifically target the emissions of service oriented companies; local, national and international targets and efforts towards an environmentally friendly world affect these companies as well. As Koivisto (2008, p.69) stated, the companies play an important role in promoting sustainable development. The environmental problems, climate change in particular, are threatening our welfare. Both economically, socially as well as ecologically. Companies, their employees and all individuals are facing challenges caused by climate change. The use and disposal of natural resources and products are human actions affecting the environment. Businesses need to acknowledge their responsibility in the fight against climate change. They need to identify the key issues of sustainable development and what their own role is in it. We are all a part of our global world and everyone’s actions matters.

## References


Agrawal, M., Pandey, D. and Pandey, J. S. (2010) Carbon footprint: current methods of estimation. *Environmental Monitoring and Assessment*, [e-journal] Vol 178, Issue 1-4, pp-135-160, doi: 10.1007/s10661-010-1678-y.

Albertao, F. (2012) Sustainable Software Development. In: Murugesan, S. and Gangadharan, G.R., 1st ed. 2012. *Harnessing Green IT : Principles and Practices.* [e-book] Chichester, UK: John Wiley & Sons, Incorporated. Available through: Aalto University Library website: https://learningcentre.aalto.fi/en/home/ [Accessed 14.8.2017]

AquAeTer. (2011) *What is Life Cycle Assessment (LCA)?.* [pdf]. WoodPoles. Available at: http://woodpoles.org/Resources/TechnicalLibrary.aspx [Accessed 15.6.2017]

Asmatulu, R. and Asmatulut. E. (2011) Importance of recycling education: a curriculum developmentat WSU. *Journal of Material Cycles and Waste Management*, [e-journal] Vol 13, Issue 2, pp. 131-138, doi: 10.1007/s10163-011-0002-4

Banerjee, R. (2015) Importance of Recycling. *IJIREEICE*, [e-journal] Vol. 3, Issue 6, pp. 53-55, doi: 10.17148/IJIREEICE.2015.3611

Becken, S. (2007) Tourists' Perception of International Air Travel's Impact on the Global Climate and Potential Climate Change Policies. *Journal of Sustainable Tourism*, [e-journal] Vol. 15, Issue 4, pp. 351–368. doi:10.2167/jost710.0

Berkhout, F., Hertin, J. (2004). De-materialising and re-materialising: digital technologies and the environment. *Futures,* [e-journal] Issue 36, 903–920. doi: 10.1016/j.futures.2004.01.003

Bilec, M., Ries, R., Matthews, S. and Sharrard A.L. (2006) Example of a Hybrid Life-Cycle Assessment of Construction Processes. *Journal of Infrastructure Systems*, [e-journal] Vol. 12, Issue 4, pp. 207-215. doi: 10.1061/(ASCE)1076-0342(2006)12:4(207)

Bird, K. (2006) *New ISO 14064 standards provide tools for assessing and supporting greenhouse gas reduction and emissions trading. ISO.* [online] Available at: https://www.iso.org/news/2006/03/Ref994.html

Bohas, A. and Poussing, N. (2016) An empirical exploration of the role of strategic and responsive corporate social responsibility in the adoption of different Green IT strategies. *Journal of Cleaner Production*, [e-journal] Vol. 122, pp. 240-251. doi: 10.1016/j.jclepro.2016.02.029

Bose, R. and Luo, X. (2011) Integrative framework for assessing firms' potential to undertake Green IT initiatives via virtualization – A theoretical perspective. *Journal of Strategic Information Systems*, [e-journal] Vol. 20, Issue 1, pp. 38-54. doi: 10.1016/j.jsis.2011.01.003

Caring for Climate. (2015) *The Business Case for responsible Corporate adaptation: Strengthening Private Sector and Community Resilience.* [pdf] UN Global Compact. Available at: http://newsroom.unfccc.int/media/544104/business-case-for-corporate-adaptation.pdf [Accessed 7.7.2017]

Carnegie Mellon University Green Design Institute. (2008a) *Economic Input-Output Life Cycle Assessment (EIO-LCA), US 2002 Purchaser Price model* [online], Available at: http://www.eiolca.net/ [Accessed 3.8.2017]

Carnegie Mellon University Green Design Institute. (2008b). *Limitations of the EIO-LCA Method and Models*. [Online] Available at: http://www.eiolca.net/Method/Limitations.html [Accessed 21.6.2017]

Chapman, L. (2007) Transport and climate change: a review. *J. Transp. Geogr*. [e-journal] Vol. 15, pp. 354–367. doi: 10.1016/j.jtrangeo.2006.11.008

Covenant of Mayors. (2010) *How to develop a Sustainable Energy Action Plan (SEAP) – Guidebook.* [online] Luxembourg: European Union. Available at: http://www.eumayors.eu/IMG/pdf/seap_guidelines_en.pdf [Accessed 8.10.2017]

Čuček L., Klemeš, J.J., Kravanja, Z. (2012) A Review of Footprint analysis tools for monitoring impacts on sustainability. *Journal of Cleaner Production,* [e-journal] Vol. 34, pp. 9-20. doi: 10.1016/j.jclepro.2012.02.036

Curran, M.A. (1993) Broad-based environmental life cycle assessment. *Environmental Science & Technology*, [e-journal] Vol 27, Issue 3, pp. 430-436. doi: 10.1021/es00040a001

Davar, E. (2000) Leontief and Walras: Input-Output and reality. *13th International Conference on Input-Output Techniques*. Macerata, Italy. 21-25 August 2000,

Duhigg, C. (2013) *The power of habit, Why we do what we do and how to change*. London: Random House Books

Dyllick, T. and Hockerts, K. (2002) Beyond the business case for corporate sustainability, *Business Strategy and the Environment*, [e-journal] Vol. 11 Issue 2, pp. 130-141, doi: 10.1002/bse.323.

East, A. J. (2008) *What is a Carbon Footprint? An overview of definitions and methodologies.* [Discussion paper]. Vegetable Industry Carbon Footprint Scoping Study. Sydney: Horticulture Australia Ltd

EEA. (2014) *Grams of CO2 per passenger kilometre* [image online] Available at: https://www.eea.europa.eu/media/infographics/co2-emissions-from-passenger-transport/view [Accessed 3.11.2017]

EEA. (2016) *Atmospheric greenhouse gas concentrations.* [online] Available at: http://www.eea.europa.eu/data-and-maps/indicators/atmospheric-greenhouse-gas-concentrations-5/assessment [Accessed 24.4.2017]

EIA. (2017) *Electric Power Monthly. Table 1.1. Net Generation by Energy Source: Total (All Sectors), 2007-July 2017.* [online] Available at: https://www.eia.gov/electricity/monthly/ [Accessed 1.10.2017]

Europaportalen. (2017) *Minskade utsläpp och kraftig tillväxt i EU.* [online] Available at: https://www.europaportalen.se/content/minskade-utslapp-och-kraftig-tillvaxt-i-eu [Accessed 9.11.2017]

European Commission. (2010) *Communication from the commission Europe 2020: A strategy for smart, sustainable and inclusive growth.* [pdf] Brussels: European Commission Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF [Accessed 5.7.2017]

European Commission. (2011) *Europe 2020 targets.* [online] Available at: http://ec.europa.eu/europe2020/targets/eu-targets/index_en.htm [Accessed 14.6.2017]

European Commission. (2012a) *Flagship initiatives.* [online] Available at: http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/flagship-initiatives/index_en.htm [Accessed 14.6.2017]

European Commission. (2012b) *Sustainable growth - for a resource efficient, greener and more competitive economy.* [online] Available at: http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/priorities/sustainable-growth/index_en.htm [Accessed 14.6.2017]

European Commission. (N.D) *The framework* [online] Available at: https://ec.europa.eu/info/strategy/european-semester/framework_en [Accessed 14.6.2017]

European Commission. (2017a) *2030 climate & energy framework*. [online] Available at: https://ec.europa.eu/clima/policies/strategies/2030_en [Accessed 15.6.2017]

European Commission. (2017b) *2050 low-carbon economy*. [online] Available at: https://ec.europa.eu/clima/policies/strategies/2050_en [Accessed 15.6.2017]

European Commission. (2017c) *Paris Agreement*. [online] Available at: https://ec.europa.eu/clima/policies/international/negotiations/paris_en [Accessed 22.6.2017]

European Commission. (2017d) *Climate Action. What we do*. [online] Available at: https://ec.europa.eu/clima/about-us/mission_en [Accessed 1.11.2017]

Eurostat. (2017) *Europe 2020 - Headline indicators: scoreboard*. [online] Available at: http://ec.europa.eu/eurostat/web/europe-2020-indicators/europe-2020-strategy/headline-indicators-scoreboard [Accessed 14.6.2017]

Finkbeiner, M. (2009) Carbon footprinting – opportunities and threats. *The International Journal of Life Cycle Assessment*; [e-journal] Dordrecht, Vol. 14, Issue 2, pp. 91-94, DOI: 10.1007/s11367-009-0064-x

Financial Times. (N.D.) *Financial Times Lexicon.* [online] Available at: http://lexicon.ft.com/Term?term=corporate-responsibility [Accessed 12.5.2017].

Gasiorowski-Denis, E. (2006) *ISO standards for life cycle assessment to promote sustainable development. International Organization for Standardization.* [online] Available at: https://www.iso.org/news/2006/07/Ref1019.html [Accessed 19.6.2017]

Hammond, G. (2007) Time to give due weight to the 'carbon footprint' issue. *Nature*, [e-journal] Vol. 445, Issue 7125, p. 256. doi: 10.1038/445256b

Hart, S.L. (1997) Beyond Greening: Strategies for a Sustainable World. *Harvard Business Review*, [e-journal] Vol. 75, Issue 1, pp. 66-76.

Hellsten, P. (2012) *Modeling the carbon footprint of construction processes.* Master's Thesis. School of Engineering, Aalto University.

Helsingin Kaupunki. (2015) *Helsingin Ilamstotiekartta - Kohti hiilineutraalia ja ilmastoon sopeutunutta kaupunkiamme.* [pdf] Helsinki: Helsingin Kaupunki. Available at: https://dev.hel.fi/paatokset/media/att/c0/c08ed49dbad17914212107a8242a3f17c462f6b4.pdf [Accessed 8.10.2017]

Hendrickson, C.T., Lave, L.B. and Matthews, H.S. (2006) *Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach*. Washington: Resources for the Future.

Hilty, L.M., Arnfalk, P., Erdmann, L., Goodman, J., Lehmann, M., Wäger, P.A. (2006) The relevance of information and communication technologies for environmental sustainability – A prospective simulation study. *Environmental Modelling and Software*, [e-journal] Vol.21, Issue 11, pp. 1618–1629. doi: 10.1016/j.envsoft.2006.05.007

Hippinen, I. and Suomi, U. (2012) *Yksittäisen kohteen CO2-päästöjen laskentaohjeistus sekä käytettävät CO2-päästökertoimet.* [pdf] Helsinki: Motiva Oy. Availalbe at: https://www.motiva.fi/files/6817/CO2-laskenta_yksittainen_kohde.pdf [Accessed 9.10.2017]

HSY. (2017a) *Avoin data: HSY:n energiatase ja khk-päästöt.* [online] Available at: https://www.hsy.fi/fi/asiantuntijalle/avoindata/Sivut/AvoinData.aspx?dataID=58 [Accessed 4.10.2017]

HSY. (2017b) *Pääkaupunkiseudun kasvihuonekaasupäästöt.* [online] Available at: https://www.hsy.fi/fi/asiantuntijalle/ilmastonmuutos/hillinta/seuranta/Sivut/Paastot.aspx [Accessed 2.10.2017].

Huang, Y.A., Weber, C.L., Matthews, H.S. (2009) World Resources Institute and World Business Council for Sustainable Development. *Environmental Science & Technology*, [e-journal] Vol 43, Issue 22, pp. 8509-8515. doi: 10.1021/es901643a

Hytönen, J. (2016) *Viisi askelta tehokkaaseen toimistotilaan.* [online] Sponda. Available at: https://www.sponda.fi/magazine/viisi-askelta-tehokkaaseen-toimistotilaan [Accessed 3.10.2017]

OECD/IEA. (2009) *Transport, energy and CO2.* [pdf] Paris: IEA Publishing. Available at: https://www.iea.org/publications/freepublications/publication/transport2009.pdf [Accessed 27.7.2017]

OECD/IEA. (2016a) *Recent trends in the OECD: energy and CO2 emissions.* [pdf] IEA Publishing. Available at: http://www.iea.org/media/statistics/Recent_Trends_in_the_OECD.pdf [Accessed 27.7.2017]

OECD/IEA. (2016b) *Key CO2 emissions trends. Excerpt from: CO2 Emissions from Fuel Combustion* [pdf] IEA Publishing. Available at: http://www.iea.org/publications/freepublications/publication/KeyCO2EmissionsTrends.pdf [Accessed 27.7.2017]

IISD. (N.D) *Topic: Sustainable Development*. [online] Available at: http://www.iisd.org/topic/sustainable-development [Accessed 17.5.2017].

IPCC. (2006) *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* [pdf] Prepared by the national Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Japan: IGES

IPCC. (2014) *Climate Change 2014: Synthesis Report.* [pdf] Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. Geneva: IPCC. Available at: http://www.ipcc.ch/report/ar5/syr/ [Accessed 25.4.2017]

ISO 14025:2006. (2006a) *Environmental labels and declarations --Type III environmental declarations -- Principles and procedures*. International Organization for Standardization. pp 25. [online] Available at: https://www.iso.org/standard/38131.html [Accessed: 24.8.2017]

ISO 14064-1:2006. (2006b) *Greenhouse gases -- Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.* International Organization for Standardization. pp 20. [online] Available at: https://www.iso.org/standard/38381.html [Accessed: 24.8.2017]

ISO 14064-2:2006. (2006c) *Greenhouse gases -- Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements*. International Organization for Standardization. pp 28. [online] Available at: https://www.iso.org/standard/38382.html [Accessed: 24.8.2017]

ISO (2013) *Greenhouse gases -- Carbon footprint of products -- Requirements and guidelines for quantification and communication*. [online] Available at: https://www.iso.org/standard/59521.html

Jenkin, T.A., Webster, J. and McShane, L. (2011) An agenda for 'Green' information technology and systems research. *Information and Organization,* [e-journal] Vol.21, Issue 1, pp. 17-40. doi: 10.1016/j.infoandorg.2010.09.003

Junnila, S. (2004) The environmental significance of facilities in service sector companies. *Emerald Group Publishing Limited,* [e-journal] Vol. 22, Issue 7, pp. 190-198. doi: 10.1108/02632770410547552

Junnila, S. (2006a) Alternative Scenarios for Managing the Environmental Performance of a Service Sector Company. *Journal of Industrial Ecology*, [e-journal] Vol. 10, Issue 4, pp. 113-131

Junnila, S. (2006b) Empirical Comparison of Process and Economic Input-Output Life Cycle Assessment in Service Industries. *Environmental Science & Technology*, [e-journal] Vol. 40, Issue 22, pp. 7070-7076. DOI: 10.1021/es0611902

Junnila, S. (2006c) Environmentally Significant Processes of Consulting, Banking and Facility Management Companies in Finland and the U.S. *International Journal of Life Cycle Assess*. [e-journal] pp. 1–10. doi: http://dx.doi.org/10.1065/lca2006.12.294

Junnila, S. (2009) Environmental Impact and Intensity of Processes in Selected Services Companies. *Journal of Industrial Ecology*. [e-journal] 13, 422–437. doi:10.1111/j.1530-9290.2009.00129.x

Kakabadse, N.K., Rozuel, C. and Lee-Davies, L. (2005) Corporate social responsibility and stakeholder approach: a conceptual review. *International Journal of Business Governance and Ethics,* [e-journal] Vol 1, Issue 4, pp. 277-302. doi: 10.1504/IJBGE.2005.006733

Koroneos, C.J. and Koroneos, Y. (2007) Renewable energy systems: the environmental impact approach. *International Journal of Global Energy Issues*, [e-journal] Vol. 27, Issue 4, pp. 425-441. doi: 10.1504/IJGEI.2007.014865

Klöpffer, W. (1997) Life cycle assessment. *Environmental Science and Pollution Research*, [e-journal] Vol. 4, Issue 4, pp. 223-228. doi: 10.1007/BF02986351

Koivisto, M. (2008) *Factors influencing environmentally responsible behaviour in the Finnish service sector.* Doctoral dissertation. Helsinki University of Technology.

Lee, C-H. and Ma, H-W. (2013) Improving the integrated hybrid LCA in the upstream scope 3 emissions inventory analysis. *The International Journal of Life Cycle Assessment*, [e-journal] Vol. 18, Issue 1, pp. 17-23. doi: 10.1007/s11367-012-0469-9 .

Lindfors, L-G., Christiansen, K., Hoffman, L., Virtanen, Y., Juntilla, V., Hanssen, O-J., Rönning, A., Ekvall, T. and Finnveden, G. (1995) *Nordic Guidelines on Life-Cycle Assessment.* Copenhagen: Nordic Council of Ministers.

Luke (2016) *Energy consumption in Finland by energy source, 2016.* [pdf] Luke. Available at: http://stat.luke.fi/sites/default/files/energian_kulutus_energialahteittain_2016.pdf [Accessed 9.10.2017]

Mackay, C. (2016) Energy efficiency: EU needs to 'think bigger'. *The Parliament Magazine,* [online] 22.4.2016. Available at: https://www.theparliamentmagazine.eu/articles/feature/energy-efficiency-eu-needs-think-bigger [Accessed: 15.6.2016]

Matthews H.S, Hendrickson, C.T. and Weber C.L. (2008) The Importance of Carbon Footprint Estimation Boundaries. *Environmental Science & Technology*, [e-journal] Vol. 42, Issue 16, pp. 5839-5842. doi: 10.1021/es703112w

Mattila, T.J., Pakarinen, S. and Sokka, L. (2010) Quantifying the Total Environmental Impacts of an Industrial Symbiosis - a Comparison of Process-, Hybrid and Input - Output Life Cycle Assessment. *Environmental Science & Technology*, [e-journal] Vol 44, Issue 11, pp. 4309-4314. doi: 10.1021/es902673m

Moir, L. (2001) "What do we mean by corporate social responsibility?", Corporate Governance: *The international journal of business in society*, [e-journal] Vol. 1 Issue: 2, pp.16-22, doi: 10.1108/EUM0000000005486.

Mongelli, I., Suh, S. and Huppes, G. (2005) A Structure Comparison of two Approaches to LCA Inventory Data, Based on the MIET and ETH Databases. *The International Journal of Life Cycle Assessment*, [e-journal] Vol 10, Issue 5, pp. 317-324. doi: 10.1065/lca2004.12.198

Murugesan, S. (2008) Harnessing Green IT: Principles and Practices. *IT Professional,* [e-journal] Vol.10, Issue 1, pp. 24-33. doi: 10.1109/MITP.2008.10.

Nasa. (2017) *Climate change: How do we know?* [online] Available at: https://climate.nasa.gov/evidence/ [Accessed 1.9.2017]

Official Statistics of Finland (OSF). (2016) *Production of electricity and heat* [e-publication]. Appendix figure 1. Electricity generation by energy source 2015. Helsinki: Statistics Finland. [online] Available at: http://www.stat.fi/til/salatuo/2015/salatuo_2015_2016-11-02_kuv_001_en.html [Accessed: 1.10.2017]

Official Statistics of Finland (OSF). (2017) *Consumer price index* [e-publication]. Appendix table 4. Year-on-year changes in the Consumer Price Index, per cent. Helsinki: Statistics Finland. [online] Available at: http://www.stat.fi/til/khi/2017/07/khi_2017_07_2017-08-14_tau_004_en.html [Accessed: 25.8.2017]

One Click LCA. (2017) LCA for BREEAM Intl/ES/UK RFO. Database version: 7.2. LCA calculation programme. Helsinki, Finland: Bionova Ltd.

Pandey, D., Agrawal, M. and Pandey, J.S. (2011) Carbon footprint: current methods of estimation. *Environmental Monitoring and Assessment*, [e-journal] Vol 178, pp. 135-160. doi: 10.1007/s10661-010-1678-y

Plambeck, E.L. (2012) Reducing greenhouse gas emissions through operations and supply chain management. *Energy Economics*, [e-journal] Vol 34, pp. 64-74. doi: 10.1016/j.eneco.2012.08.031

Plepys, A. (2002) The grey side of ICT. Environ. Impact Assess. Rev., *Sustainability in the Information Society* [e-journal] Vol. 22, Issue 5, pp.509–523. doi:10.1016/S0195-9255(02)00025-2

Rake, M and Grayson, D. (2009) Embedding corporate responsibility and sustainability – everybody's business. *Corporate Governance* [e-journal] Vol. 9 Issue 4, pp.395-399, doi: 10.1108/14720700910984945.

Ramanathan,V. and Feng, Y. (2009) Air pollution, greenhouse gases and climate change: Global and regional perspectives. *Atmospheric Environment,* [e-journal] Vol. 43, pp. 37-50. doi:10.1016/j.atmosenv.2008.09.063

Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. Foley. (2009) Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society*, [e-journal] Vol. 14, Issue 2, Art. 32. [Online] Available at: http://www.ecologyandsociety.org/vol14/iss2/art32/ [Accessed 10.8.2017]

Rosenblum, J., Hendrickson, C. and Horvath, A. (2000) Environmental Implications of Service Industries. *Environmental Science & Technology*, [e-journal] Vol. 34, Issue 22, pp 4669-4676. doi: 10.1021/es9914083.

Ruth, S. (2011) Reducing ICT-related Carbon Emissions: An Exemplar for Global Energy Policy? *IETE Technical Review*, [e-journal] Vol 28, Issue 3. Invited Paper. doi: 10.4103/0256-4602.81229

SDG Compass. (2015) *SDG Compass: Home.* [online] Available at: https://sdgcompass.org/ [Accessed 6.7.2017]

Seppälä, J., Mäenpää, I., Koskela, S., Mattila, T., Nissinen, A., Katajajuuri, J-M., Härmä, T., Korhonen, M-R., Saarinen, M. and Virtanen, Y. (2009) *Suomen kansantalouden materiaalivirtojen ympäristövaikutusten arviointi ENVIMAT-mallilla.* [pdf] Helsinki: SYKE.

Silberg, B. (2016) *Why a half-degree temperature rise is a big deal.* Nasa Global Climate Change. [online] Available at: https://climate.nasa.gov/news/2458/why-a-half-degree-temperature-rise-is-a-big-deal/ [Accessed 25.4.2017].

Sinden, G. (2009) The contribution of PAS 2050 to the evolution of international greenhouse gas emission standards. *The International Journal of Life Cycle Assessment*, [e-journal] Vol 14, Issue 3, pp. 195-203. doi: 10.1007/s11367-009-0079-3

Staufenberg, J. (2016) EU countries meet 2020 carbon-cutting targets 'six years early'. *The Independent,* [online] Available at: http://www.independent.co.uk/news/world/europe/eu-countries-2020-six-years-climate-change-environment-carbon-cutting-emissions-targets-a7097916.html [Accessed: 15.6.2016]

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., Vries, W. de, Wit, C.A. de, Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B., Sörlin, S. (2015) Planetary boundaries: Guiding human development on a changing planet. *Science,* [e-journal] Vol. 347, Issue 6223, pp. 1259855-1 – 1259855-10. doi:10.1126/science.1259855

Steigerwald, B. and Agrawal, A. (2012) Green Software. In: Murugesan, S. and Gangadharan, G.R., 1st ed. (2012). *Harnessing Green IT : Principles and Practices.* [e-book] Chichester, UK: John Wiley & Sons, Incorporated. Available through: Aalto University Library website: https://learningcentre.aalto.fi/en/home/ [Accessed 14.8.2017]

Suh, S., Lenzen, M., Treloar, G.J., Hondo, H., Horvath, A., Huppes, G., Jolliett, O., Klann, U., Krewitt, W., Moriguchi, Y., Munksgaard, J. and Norris, G.A. (2004) "System Boundary Selection in Life-Cycle Inventories Using Hybrid Approaches", *Environmental Science & Technology*, [e-journal] Vol. 38, Issue 3, pp. 657-664. doi: 10.1021/es0263745

Säynäjoki, A., Heinonen, J. and Junnila S. (2011) Carbon Footprint Assessment of a Residential Development Project. *International Journal of Environmental Science and Development*, Vol. 2, Issue 2, pp. 116-123.

Treloar, G.J., Love, P.E.D., Fanarin, O.O. and Iyer-Raniga, U. (2000) A hybrid life cycle assessment method for construction. *Construction Management and Economics*, [e-journal] Vol 18, pp.5-9. doi: 10.1080/014461900370898

Tommola, A. (2017) Pyöräily on hyväksi aivoille ja vähentää stressiä – Viisi syytä pyöräily töihin. *Helsingin Sanomat.* [online] Available at: https://www.hs.fi/elama/art-2000005337493.html [Accessed 17.10.2017]

United Nations. (N.D.a) *Climate change affects everyone. Sustainable development goals.* [online] Available at: http://www.un.org/sustainabledevelopment/climatechange/ [Accessed 22.6.2017]

United Nations. (N.D.b) *The Sustainable Development Agenda. Sustainable development goals*. [online] Available at: http://www.un.org/sustainabledevelopment/development-agenda/ [Accessed 22.6.2017]

United Nations Global Compact. (N.D.) *Who we are.* [online] Available at: https://www.unglobalcompact.org/what-is-gc/mission [Accessed 6.7.2017]

van Marrewijk, M. (2003) "Concepts and Definitions of CSR and Corporate Sustainability: Between Agency and Communion", *Journal of Business Ethics*, [e-journal] Vol 44, Issue 2, pp. 95-105, ISSN: 01674544.

von Hauff, M. and Kleine, A. (2009) "Sustainability-Driven Implementation of Corporate Social Responsibility: Application of the Integrative Sustainability Triangle", *Journal of Business Ethics*, [e-journal] Vol 85, pp. 517-533, doi: 10.1007/s10551-009-0212-z.

VTT Technical Research Centre of Finland Ltd. (2017) *LIPASTO unit emissions -database.* [online] Available at: http://lipasto.vtt.fi/yksikkopaastot/ [Accessed 2.10.2017].

Väisänen, S. (2014) *Greenhouse gas emissions from peat and biomass-derived fuels, electricity and heat — Estimation of various production chains by using LCA methodology.* Doctoral Thesis. Lappeenranta University of Technology. Lappeenranta. pp. 161. ISSN 1456-4491.

Watson, R. T., Boudreau, M. C., Chen, A., & Huber, M. H. (2008) Green IS: Building sustainable business practices. In R. T. Watson (Ed.), *Information Systems*. [e-book] Athens, GA, USA: Global Text Project.

Wiedmann, T. and Minx, J. (2007) *A Definition of 'Carbon Footprint'. ISA Research and Consulting.* Durham United Kingdom. Research Report. [online] Available at: http://buildinggreenusa.org/Carbon%20Footprint/A%20Definition%20of%20Carbon%20Footprint.pdf [Accessed 2.6.2017]

WRI and WBCSD. (2011) *GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard*, USA: World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD), ISBN 978-1-56973-772-9

WRI and WBCSD. (2004) *GHG Protocol A Corporate Accounting and Reporting Standard,* USA: World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD), ISBN 1-56973-568-9

Wright, A.L., Kemp, S. and Williams, I. (2011) 'Carbon footprinting': towards a universally accepted definition. *Carbon Management,* [e-journal] Vol. 2, Issue 1, pp. 61-72. DOI: 10.4155/ cmt.10.39

WWF. (2017) *Ilmastolaskuri, Laskentaperusteet.* [online] Available at: http://www.ilmastolaskuri.fi/fi/calculation-basis?country=2&year=10746 [Accessed 12.9.2017]

# Appendix A Online Personnel Survey

**Personnel Survey Futurice**

Futurice is conducting a commuting, energy usage and recycling habit survey for the employees at the Helsinki Office.

Answers to these survey questions will help us understand how the employees commuting, energy usage and recycling habits affect the environmental impact of Futurice and how satisfied the employees are within certain areas.

Completing the survey should not take more than 10 minutes and it is completely anonymous. Please respond honestly and feel free to add any comments. Please reply no later than **Friday, Jun 2nd**.

Thank you for taking a few moments to complete the survey.

*The commuting habit survey is a part of the carbon footprint calculation done for Futurice as a part of the Master's Thesis "The Environmental Impact of Service Oriented Companies" written by Jennifer Pitkänen at Green Building Partners Oy.*

## 1) Background information

### 1-1) Distance to work (one-way)

_____ km
_____ min

## 2) Commuting

### 2-1) Commuting habits

How do you usually commute to and from work? Please evaluate how you commute to work on a normal week in average. Fill in how many days a week (x/5 working days) you on average use the different transport options in winter/autumn and in summer/spring.

| **Transportation** | **Winter/Autumn** (5 days in total) | **Summer/Spring** (5 days in total) |
|---|---|---|
| Public transportation (bus, metro, train, tram, etc.) | | |
| Car, alone | | |
| Carpool | | |
| Motorcycle | | |
| Bicycle | | |
| By foot | | |
| Remote work | | |
| Other, how | | |

**2-2) If you come by car to work is it a normal, hybrid or electric car? (circle the correct option)**

**2 -2-1) If it is a low emitting car, what model is it (brand, model, year)?** Alternatively fill in the CO2 (g/km) emissions: ______________

**2-3) Alternative Transportation**

**2-3-1) Could you use alternative transportation options to a greater extent for commuting?**

| | No, I already use it as much as possible | Easily | Fairly easily | I could consider it | Only if there is no other option |
|---|---|---|---|---|---|
| Public transport | | | | | |
| Bicycle (spring to autumn) | | | | | |
| Bicycle (year around) | | | | | |

Comments (e.g. is there something Futurice could do to increase your usage of alternative transportation?):___________________________________________________

# 3) Videoconferencing

**3.1) Are you utilizing videoconferencing or other teleconferencing methods in your work?**

Daily / Almost Daily __ At least once a week__ 1-3 times a month__

Less than once a month__ Almost never__

Estimate the share (%) of video-/teleconferencing meetings of all meetings (with people from outside the Helsinki office): ____________

Comments:_____________________________________________________________

**3.2) How satisfied are you with the video/teleconferencing possibilities?**

+ 2 Very satisfied__ + 1 Satisfied__ 0 Moderate__ - 1 Dissatisfied__ - 2 Very dissatisfied

If you are dissatisfied in some respect, please indicate the cause:

____________________________________________________

**3.3) Could you utilize video/teleconferencing to a greater extent in your work?**

I already use it as much as possible __ Very easily__ Fairly easily__ Possibly__

Not so easily__

Comments (e.g. is there something Futurice could do to increase your usage of video/teleconferencing?):

## 4) Energy usage

**4.1) When leaving your workspace how long does it take for your <u>laptop</u> to go to sleep?**

Immediately (I turn it off)__ 1-15 minutes__ 16-30 minutes__ More than 30 minutes__

It never goes to sleep__

**4.2) When leaving your workspace how long does it take for your <u>desktop computer</u> to go to sleep?**

Immediately (I turn it off)__ 1-15 minutes__ 16-30 minutes__ More than 30 minutes__

It never goes to sleep__

## 5) Recycling and waste management

**5.1) How often do you recycle waste that is recyclable?**

Always__ Almost always__ Often__ Not so often__ Never__

**5.2) If you recycle, which materials do you normally recycle:**

Paper__ Cardboard__ Glass__ Metal__ Bio-waste__ Energy waste/Plastics__

**5.3) How easy do you find it to recycle in the office?**

+ 2 Very easy__ + 1 Easy__ 0 Relatively easy__ - 1 Difficult__ - 2 Impossible__

Comments:

# Appendix B Matching of accounting records and IO-data

| Accounting data Futurice | | Carniege-Mellon | ENVIMAT |
|---|---|---|---|
| Purchased services | Accounting | Accounting and bookkeeping services | C126 Rahoituspalvelut |
| | Data transfer costs | Telecommunications | C081 Tietoliikenne |
| | Legal- and consulting services | Legal services | C127 Muut muualla luokittelemattomat palvelut |
| | Mailing and courier costs | Couriers and messengers | C081 Tietoliikenne |
| | Money transaction costs | Nondepository credit intermediation | C126 Rahoituspalvelut |
| | Other administrative costs | Office Administrative Services | C127 Muut muualla luokittelemattomat palvelut |
| | Telephone costs | Telecommunications | C081 Tietoliikenne |
| | Viestiliikennekulut | Internet service providers and web search | C081 Tietoliikenne |
| | Other insurances | Insurance carriers | C125 Vakuutus |
| | Computer servicing: repair & install. | Electronic equipment repair and maintenance | C091 Audiovisuaaliset, valokuvaus- ja |
| | Hosting palvelut, alv | Data Processing, Hosting, and Related | C127 Muut muualla luokittelemattomat palvelut |
| | Serverihosting | Data Processing, Hosting, and Related | C081 Tietoliikenne |
| | Software, upgrading, maintenance | Other computer related services including computer facilities management | C091 Audiovisuaaliset, valokuvaus- ja tietojenkäsittelylaitteet |
| | Occupational health service | Offices of physicians, dentists and other health practitioners | C062 Avohoitopalvelut |
| | Other social security expenses | Funds, trusts and other financial vehicles | C124 Sosiaaliturva |
| | Recreation and free-time activities | Other amusement, gambling and recreation | C094 Virkistys- ja kulttuuripalvelut |
| | Travel insurance | Insurance agencies, brokerages and related | C125 Vakuutus |
| Activities within company | Entertainment events | Other amusement, gambling and recreation | C094 Virkistys- ja kulttuuripalvelut |
| | Other entertainment costs | Other amusement, gambling and recreation | C094 Virkistys- ja kulttuuripalvelut |
| | Advertising | Advertising and related services | C127 Muut muualla luokittelemattomat palvelut |
| | Fairs and exhibitions | Management consulting services | C127 Muut muualla luokittelemattomat palvelut |
| | Marketing costs | Management consulting services | C127 Muut muualla luokittelemattomat palvelut |
| | Other advertising costs | Advertising and related services | C127 Muut muualla luokittelemattomat palvelut |
| | PR-costs | Management consulting services | C127 Muut muualla luokittelemattomat palvelut |
| | HR Messut | Management consulting services | C127 Muut muualla luokittelemattomat palvelut |
| | Recruiting costs | Employment services | C127 Muut muualla luokittelemattomat palvelut |
| | Training of personnel | Other educational services | C100 Koulutus |
| | Meeting and negotiation costs | Food services and drinking places | C111 Ravitsemispalvelut |
| | Internal meetings & staff parties | Food services and drinking places | C111 Ravitsemispalvelut |

| | | | |
|---|---|---|---|
| **Office equipment and supplies** | Comp. purchases | Electronic computer manufacturing | C091 Audiovisuaaliset, valokuvaus- ja tietojenkäsittelylaitteet |
| | Computer and software rent | Commercial and industrial machinery and equipment rental and leasing | C091 Audiovisuaaliset, valokuvaus- ja tietojenkäsittelylaitteet |
| | IT-laitehankinnat(<3 v kalusto) alv yl | Telephone apparatus | C091 Audiovisuaaliset, valokuvaus- ja tietojenkäsittelylaitteet |
| | Leasing of machinery & equipment | Commercial and industrial machinery and equipment rental and leasing | C091 Audiovisuaaliset, valokuvaus- ja tietojenkäsittelylaitteet |
| | Puhelinhankinnat | Broadcasting and wireless communications equipment | C081 Tietoliikenne |
| | Books | Book publishers | C095 Sanomalehdet, kirjat ja paperitarvikkeet |
| | Newspapers | Newspaper publishers | C095 Sanomalehdet, kirjat ja paperitarvikkeet |
| | Office equipment | Office supplies (except paper) manufacturing | C095 Sanomalehdet, kirjat ja paperitarvikkeet |
| | Paper and printing costs | Stationery product manufacturing | C095 Sanomalehdet, kirjat ja paperitarvikkeet |
| | Business presents | Pottery, ceramics, and plumbing fixture | C094 Virkistys- ja kulttuuripalvelut |
| | Coffee accessories (coffe estimated 50 % of price) | Coffee and tea manufacturing | C012 Alkoholittomat juomat |
| | Cofee cups estiamted 50 % of price | All other converted paper product manufacturing | C056 Tavarat |
| | Meals for personnel/luncheon | Food services and drinking places | C111 Ravitsemispalvelut |
| | Presents to personnel | Pottery, ceramics, and plumbing fixture | C123 Muualla luokittelemattomat henkilökohtaiset |
| | Meals during travel | Food services and drinking places | C111 Ravitsemispalvelut |
| **Building premises** | Cleaning and sanitation | Soap and cleaning compound manufacturing | C044 Muut asumiseen liittyvät palvelut |
| | Electricity and gas | Power generation and supply | C0451 Sähkö |
| | Guarding and security | Investigation and security services | C044 Muut asumiseen liittyvät palvelut |
| | Other expenses of premises | Waste management and remediation services | C044 Muut asumiseen liittyvät palvelut |
| | Use and maintenance | Facilities support services | C043 Asunnon ylläpito ja korjaus |
| | Rent on garage&reserved parking | Other personal services | C041 Todelliset asumisvuokrat |
| | Rent on premises(maintenance,15 %) | Nonresidential maintenance and repair | C043 Asunnon ylläpito ja korjaus |
| | Rent on premises (capital rent,85 %) | Real Estate | C041 Todelliset asumisvuokrat |
| **Business Travel** | Hotel and other accommodation | Hotels and motels, including casion hotels | C112 Majoituspalvelut |
| | Kilometre allowance | Transit and ground passenger transportation | C072 Yksityisten kulkuvälineiden käyttö |
| | Other travel costs | Travel arrangement and reservation services | P312Y Matkailumenot ulkomailla |
| | Parking costs | Other personal services | C072 Yksityisten kulkuvälineiden käyttö |
| | Taxi | Transit and ground passenger transportation | C0732 Linja-auto- ja taksimatkat |
| | Tickets (approximated air transport 60 %) | Air transportation | C0733 Lentomatkat |
| | Tickets (approximated train transport 30 %) | Rail transportation | C0731 Juna-, raitiovaunu- ja metromatkat |
| | Tickets (approximated bus transport 10 %) | Transit and ground passenger transportation | C0732 Linja-auto- ja taksimatkat |